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TRANSCRIPT OF RECORD.

SUPREME COURT OF THE UNITED STATES.

OCTOBER TERM, 1883.

No. ~~113~~ 107

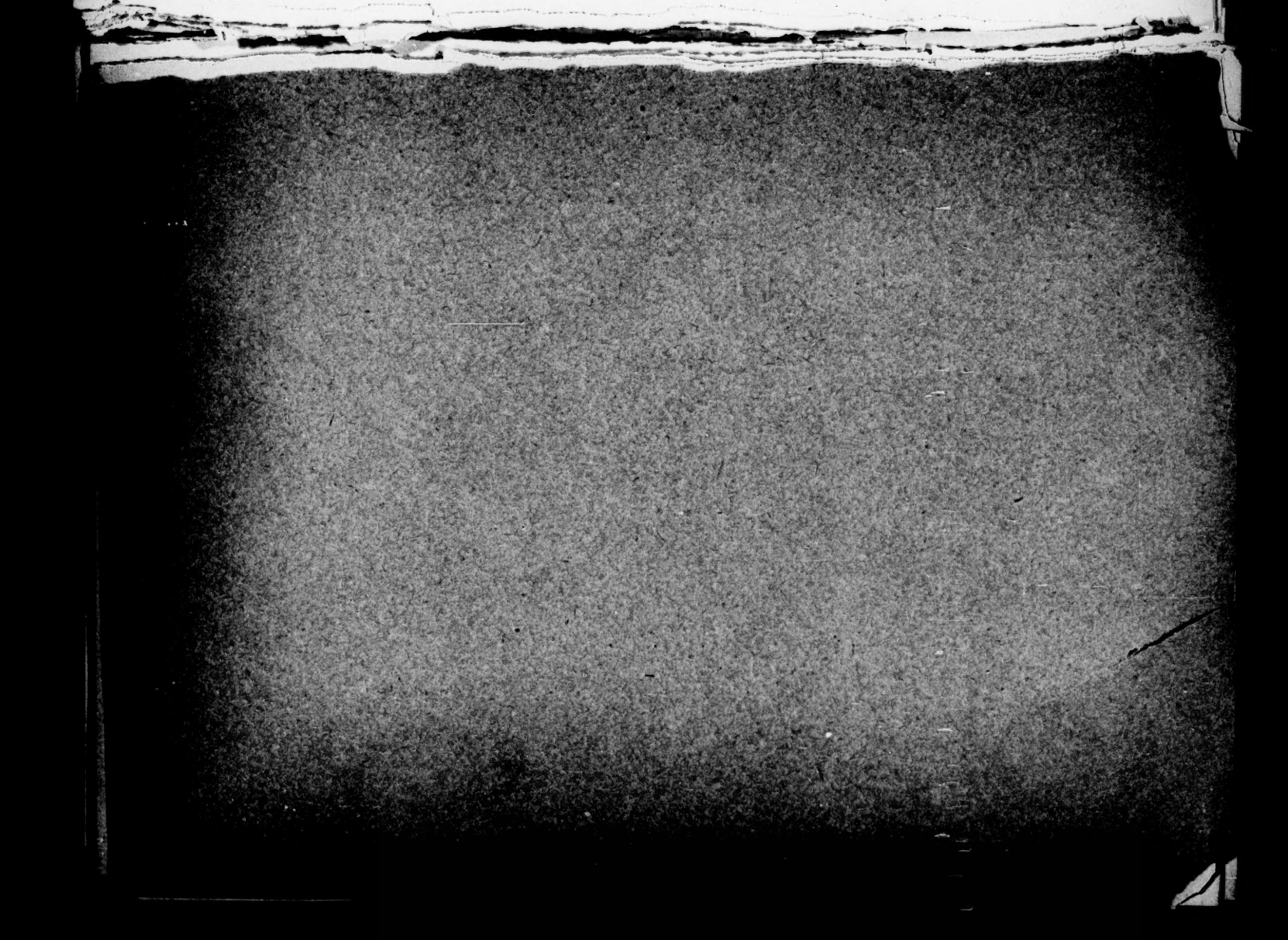
AMOS E. DOLBEAR, FRANCIS M. HOLMES, AND HENRY B. METCALF, APPELLANTS,

vs.

THE AMERICAN BELL TELEPHONE COMPANY.

APPEAL FROM THE CIRCUIT COURT OF THE UNITED STATES FOR THE DISTRICT OF MASSACHUSETTS.

FILED OCTOBER 8, 1883.



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INDEX.

	Original.	Print.
Caption	1	1
Bill of complaint	1*b*	1
Order for temporary injunction	13	13
Answer	15	15
Replication	28*a*	29
Hearing	28*b*	29
Final decree	28*b*	29
Order allowing appeal	29*a*	30
Evidence for complainants	30	30
Exhibit—Assignment, Bell to Hubbard. Assignment of Alex. Graham Bell to Gardiner G. Hubbard, July 28, 1877	30	30
Exhibit—Assignment, Hubbard to Bell Telephone Co. Assignment of Gardiner G. Hubbard to the Bell Telephone Co., July 20, 1878	31	31
Exhibit—Assignment, Bell Telephone Co. to American Bell Telephone Co. Assignment of the Bell Telephone Co. to the American Bell Telephone Co., April 23, 1881	33	33
Exhibit—Charter, American Bell Telephone Co. Act to incorporate the American Bell Telephone Co., March 19, 1880	34	34

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	Original.	Print.
Exhibit—Certificate of incorporation, American Bell Telephone Co. Certificate of the incorporation of the American Bell Telephone Co., October 13, 1880	36	36
Stipulation as to evidence, &c.	38	38
Moving papers on motion for preliminary injunction	38*b*	39
Letters patent No. 174,465 granted Alex. Graham Bell, March 7, 1876	38*b*	39
Letters patent No. 186,787 granted Alex. Graham Bell, January 30, 1877	46*a*	51
Affidavit of Alex. Graham Bell	55	63
Chas. R. Cross	61	69
Thos. A. Watson	87	95
Edward Davis	167	175
Albert H. Chapman	170	178
Theo. N. Vail	173	181
Article from Scientific American by A. E. Dolbear, entitled "A New System of Telephony"	178	187
Evidence for defendants	189½	199
Affidavit of Amos E. Dolbear	189	199
Frank L. Pope	203	213
John Trowbridge	214	224
Moses G. Farmer	215	225
Henry C. Buck	218	228
Evidence for complainants in reply	225½	235
Affidavit of Chas. R. Cross	225	235
George D'Infreville	272	282
Arthur W. Wright	278	288
Extract from deposition of Chas R. Cross in Dowd suit	297	307
" " T. A. Watson "	298	308
Evidence for defendants in rebuttal	301	311
Affidavit of Frank L. Pope	301	311
Henry C. Buck	313	323
Deposition of Chas. R. Cross in Dowd suit	320	330
Edw. S. Renwick in Dowd suit	321	331
Amos E. Dolbear	331	341
Henry C. Buck	474	484
Walter R. Eaton	482	492
Evidence for complainants in reply	487	497
Deposition of Chas. R. Cross	487	497
List of publications put in evidence	529	565
Defendants' Exhibit No. 1—Didaskalia Bourseul Article	531	569
Complainants' Exhibit No. 2—Du Moncel's Bourseul	532	570
3—Du Moncel Article	534	572
Defendants' Exhibit No. 4—Clemens' Suggestion	535	573
5—Report of Reis Lecture	535	573
6—Reis Lecture	537	575
7—Reis Exhibition of 1861	544	588
8—Reis-Legat Article	547	591
9, 10 and 11—Industrial Gazette	553	601
12—Böttger's Article	557	605
13, 14 and 15—(same as No. 12)	560	608
Complainants' Exhibit No. 16—Jahresbericht des Physicalischen vereins zu Frankfurt am main fur das Rechnungs jahr. 1862–1863, p. 35	561	609

	Original.	Print.
Complainants' Exhibit No. 17—Reis' letter to Ladd	561	609
18—British Association on Reis	564	612
19— " " Report on Reis	565	613
Defendants' Exhibit No. 20—Prospectus of Mr. Albert	566	614
Complainants' Exhibit No. 21—Circular of Reis	567	615
22—Reis' Descriptive Circular	568	616
Defendants' Exhibit No. 23—(same as No. 8)	570	618
24—Böttger's Account of Reis' Improved Apparatus	571	619
25—Reis' Improved Apparatus	572	620
26—Gartenlaube Reis Improved Apparatus	572	620
Complainants' Exhibit No. 27—Cosmos Description of Reis	577	625
28—Clifton's Description of Reis	581	629
29—Kœnig's " "	581	629
Defendants' Exhibit No. 30—Pisko's Description of Reis	582	630
31—Reis' Prospectus. From Pisko	591	641
Complainants' Exhibit No. 32—Kuhn's Description of Reis	593	643
33—Hassler's Description of Reis	599	649
34—Albert's Catalogue of 1866	600	650
Defendants' Exhibit No. 35—Ferguson's Description of Reis	601	651
Complainants' Exhibit No. 36—Müller's-Pouillet's Description of Reis	603	653
Defendants' Exhibit No. 37—Dr. Van Der Weyde's Reis	606	656
38—(same as No. 37)	610	660
Complainants' Exhibit No. 39—American Association on Reis	610	660
40— " " "	610	660
Defendants' Exhibit No. 41—Baile's Article	611	661
Complainants' Exhibit No. 42—Albert's Catalogue of 1873	613	663
43—Dr. Van Der Weyde's Second Article	614	664
44—South Kensington Reis	617	667
45—Preece on Reis	618	668
46—Ganot's Description of Reis	619	669
Dolbear on Reis	619	669
Second Extract from Dolbear's Book	625	677
Dolbear's Description of a Modified Reis Transmitter	629	681
Letters Patent No. 78,495 granted C. F. Varley, June 2, 1868	630*a*	683
English Patent No. 1,044 granted C. F. Varley, 1870	632*a*	691
Letters Patent No. 239,742 granted A. E. Dolbear, April 5, 1881	642*a*	709
240,578 " " " " 26, 1881	644*a*	715
Opinion on granting temporary injunction	647	719
final hearing	656	727
settlement of final decree	658	729
Clerk's certificate	659	729
Bond	660	730

UNITED STATES OF AMERICA, *Massachusetts District,* } ss:

At a circuit court of the United States for the first circuit, begun and holden at Boston, within and for the district of Massachusetts, on Tuesday, the fifteenth day of May, in the year of our Lord one thousand eight hundred and eighty-three. Before the,

HONORABLE JOHN LOWELL,
Circuit Judge.

IN EQUITY.

AMERICAN BELL TELEPHONE COMPANY, Complainant,

v.

AMOS E. DOLBEAR *et al.*, Defendants.

The bill of complaint in this cause was filed in the clerk's office on the tenth day of October, A. D. 1881, and was duly entered at the May term of this court, A. D. 1881, and is in the words and figures following, namely:

BILL OF COMPLAINT.

[Filed Oct. 10, 1881.]

To the Honorable the Justices of the Circuit Court of the United States for the District of Massachusetts:

The American Bell Telephone Company, a corporation duly established under the laws of the Commonwealth of Massachusetts, brings this its bill of complaint against Amos E. Dolbear, of the city of Somerville, State of Massachusetts; Francis M. Holmes, of the city of Boston, State of Massachusetts; and Henry B. Metcalf, of the city of Pawtucket, State of Rhode Island.

And thereupon your orator complains and says:

1. That before the seventh day of March, 1876, Alexander Graham Bell, then of Salem, in said Commonwealth, being the original and first inventor of a new and useful improvement in telegraphy, which was never known or used before his invention thereof, and which had at the time of his application been in public use or on sale for more than two years, made application according to law for

letters patent of the United States to be granted to him therefor; upon which application, due proceedings being had in all respects, said letters patent were on the seventh day of March, 1876, granted, issued, and delivered to said Alexander Graham Bell, signed by the Secretary of the Interior and countersigned by the Commissioner of Patents, and numbered 174465, whereby there was secured to said Alexander Graham Bell, his heirs, administrators, or assigns, for the term of seventeen years from the said seventh day of March 1876, the full and exclusive right and liberty of making, constructing, using, and vending to others to be used the said improvement, a description whereof is given in the words of the said Bell, in the schedule annexed to said patent, and formed a part thereof, as by said patent, numbered 174465, or a copy thereof, here in court to be produced, will fully appear.

2. Before the thirtieth day of January, 1877, the said Alexander Graham Bell, being the original and first inventor of another new and useful improvement in electric telegraphy, which was never known or used before his invention thereof, and which had not at the time of his application been in public use or on sale for more than two years, made application according to law for letters patent of the United States to be granted to him therefor; upon which application, due proceedings being had in all respects, said letters patent were on said thirtieth day of January, 1877, granted, issued, and delivered unto said Bell, signed by the Secretary of the Interior and countersigned by the Commissioner of Patents, and numbered 186787, whereby there was secured to said Bell, his heirs, administrators, or assigns, for the term of seventeen years from the said thirtieth day of January, 1877, the full and exclusive right and liberty of making, constructing, using, and vending to others to be used the said improvement, the description whereof is given in the words of said Bell in the schedule annexed to said last-named patent, and forming a part thereof, as by said patent numbered 186787, or a copy thereof, here in court to be produced, will fully appear.

3. Said Alexander Graham Bell assigned said letters patent, numbered respectively 174465 and 186787, to Gardiner G. Hubbard, trustee, by deed of assignment dated July 9, 1877, and recorded at the Patent Office July 28, 1877, liber R^{22}, page 399 of Transfers of Patents. That said Gardiner G. Hubbard, trustee, assigned said letters patent, numbered respectively 174465, and 186787, to the Bell Telephone Company, by assign-

[*Amendment to Bill. At end of paragraph* 4, *add the following.*]
and by an instrument in writing, dated April 23, 1881, recorded at the Patent Office, July 6, 1881, Liber B 27, page 101, of Transfers of Patents.

ment dated July 20, 1878, and recorded at the Patent Office, Oct. 3, 1878, Liber Y[22], page 460 of Transfers of Patents.

4. Said Bell Telephone Company has granted the same to your orator, the American Bell Telephone Company, by an instrument in writing, dated June 22, 1880, and recorded at the Patent Office, June 24, 1880, Liber I[25], page 282 of Transfers of Patents.

5. The sole right to manufacture electric speaking telephones under said patents thereby became and still is vested in the said American Bell Telephone Company; that the only right granted to or possessed by any persons other than the said American Bell Telephone Company under said patents has been and is the right to use telephones procured from said American Bell Telephone Company and its predecessors, upon payment of stated royalties under said two patents to the said American Bell Telephone Company.

6. Electric speaking telephones had never been publicly known or used before the grant of said patent, and were first publicly made known and first introduced into public use by said Bell and his licensees under said Bell patent; and but for the unlawful acts of the defendants hereinafter complained of, your orator would be in the full and exclusive enjoyment of said rights.

7. Your orator further shows, that after the grant of said Letters Patent, the inventions therein described and claimed, or substantial and material parts of the same, embodied in instruments known as Bell telephones, and in instruments known as Blake transmitters, were before July, 1877, and January, 1879, respectively introduced into general public use by the said Bell, the said Hubbard, trustee, the said Bell Telephone Company and your orator. That many thousands of persons have put the said inventions into daily use under the authority and license of the said Hubbard and your orator, and its predecessors, and those holding rights or licenses under them, and have paid for such use of said inventions the amount fixed by the owners of said patents as a reasonable compensation therefor, such payments amounting in the aggregate to many thousands of dollars. That telephone exchanges now exist in more than five hundred towns and cities of the United States, and in every State thereof, and exist in substantially every city of the

United States having more than 15,000 inhabitants, and in many smaller places; and all said exchanges use telephones licensed by your orator, the American Bell Telephone Company, and its predecessors, as owners of said Bell patents, and pay royalty therefor to your said orator. That the fact that said Bell was the original and first inventor of said inventions, and that the patents above named are good and valid patents, has been generally recognized and acknowledged by those who have used the inventions and the public generally, in all parts of the United States, and the claims of the said Bell, Hubbard and your orator and its said predecessors, to the exclusive right to the said inventions under said patents have been generally acknowledged and acquiesced in. That from time to time several persons have attempted to make, sell and use telephones, or parts thereof, embracing said inventions, but that in such cases said Hubbard while owner of, and your orator and its said predecessors since they have owned said patents, have immediately upon hearing of such acts or attempts notified such parties to desist therefrom, and that such parties have generally, upon receiving such notices, complied therewith, and acquiesced in and recognized as valid the clai ns of said Hubbard and your orator under said patents; and said Bell, said Hubbard and your orator have always asserted and maintained, and but for the wrongful acts of the defendants would and have hitherto almost universally enjoyed the sole and exclusive right to practise said inventions; that they have not acquiesced in any infringement of their exclusive rights; that no persons or parties except your orator, the American Bell Telephone Company, and its licensees are now openly engaged in the manufacture or use of electric speaking telephones, save and excepting the defendants and possibly a few small infringers whom your orator is about to proceed against; and that the said exclusive rights of your orator are of great value to it.

8. There are now in use more than 160,000 electric speaking telephones licensed by and paying royalty to your orator, the American Bell Telephone Company; that the owners of said Bell patents, and those who now are or heretofore have been licensed by them, have devoted great time and attention and large sums of money to the development of the telephone and the introduction thereof into

extensive use, and to the proper construction of the most suitable telephone lines and systems and telephonic appliances, and have constructed many thousand miles of telephone lines for use with telephones owned by your orator, the American Bell Telephone Company, and licensed by it for such use; and that nothing which the defendants or either of them have done has contributed in any substantial way to the development of the telephone, or the introduction thereof into use.

9. From time to time sundry persons have undertaken to manufacture and use electric speaking telephones, and to infringe the said patents; that the owners of said patents have required them to stop, and for the most part they have, upon being so notified, desisted from such infringement; that your orator, the American Bell Telephone Company, and its predecessors, owners of said Bell patents, have brought suit in the courts of the United States and obtained injunctions and decrees against such infringers; and among the suits so brought and which have resulted in injunctions or decrees are the following: —

10. The said exclusive rights of said Bell, and your orator, the American Bell Telephone Company, and its predecessors, as his assigns and grantees, have never been openly or publicly violated, to any considerable extent, except at one time and in the year 1878, by the Western Union Telegraph Company, and by the Gold and Stock Telegraph Company, and by the American Speaking Telephone Company, said three corporations having associated themselves together for that purpose; that said Bell Telephone Company brought its bill in equity in the Circuit Court of the United States for the District of Massachusetts, against Peter A. Dowd, an agent of said associated companies, engaged in the business of using their infringing telephones, and in said suit complained of the defendant that he had infringed the fifth claim of said patent 174,465; and also complained that he had infringed the third, sixth, seventh and eighth claims of said patent 186,787; the said associated corporations assumed the defence of said suit, and employed in said defence their counsel and experts learned in the law and skilled in the art; in said suit evidence was taken and completed by the complainants

use of a microphone

in chief, and by the defendant in defence, and by the complainants in reply; and thereupon, upon consideration of said proof, and the opinions of their professional advisers, the defendant and said corporations became satisfied that said Bell was the true, original and first inventor of the electric speaking telephone, and the inventions covered by said patents; whereupon they submitted to the said claims of the complainants, and agreed to desist from further infringements, and have since desisted from further infringements, and placed and caused to be placed all telephones within their power or control under license under said Bell patents, and paid or caused to be paid the usual and customary yearly royalties therefor habitually charged by the assigns of said Bell to other parties for like uses, and agreed that they would not thereafter make electric speaking telephones, and would not thereafter use electric speaking telephones, except such as should be made and furnished to them by your orator or the assigns of said Bell, and under license under said Bell patents, and that for the use of the same they should pay not less than the usual and accustomed royalties from time to time charged to others by your orator; and in accordance with the said advice of counsel of said telegraph companies a final decree was thereafter made and entered in said suit for the complainant, with the consent of the defendant Dowd, and in and by said decree the said two Bell patents were adjudged and declared to be valid patents, and the defendant was perpetually enjoined from infringing the same.

11. In the year 1880 the People's Telephone Company, a corporation organized under the laws of the State of New York, and Frank A. Klemm, Joseph Loth, Julius Bien, Marcus Marx, Auguste H. Girard, John N. Goodwin, Ernest Marx, Edgar W. Chellis, Richard C. McCormick, Henry D. Cooke, Jr., Max L. Gutman, Moritz Loth and Simon Wolf, did make, sell and use, and threaten to make, sell and use certain electric speaking telephones, some of which were known as the "Klemm" telephones, and some of which were known as the "Tisdel" telephones; that said defendants owned the alleged inventions of Frank A. Klemm and of Abner G. Tisdel, and of Daniel Drawbaugh, relating to electric speaking telephones; that thereupon your orator, the American Bell

Telephone Company, and the Metropolitan Telephone and Telegraph Company, a licensee of said American Bell Telephone Company, did, in the Circuit Court of the United States for the Southern District of New York, file a bill in equity against all of said parties, complaining that such acts done and threatened infringed the rights secured to the said orators by the said two Bell patents, 174,465 and 186,787; and did also move for an injunction thereon *pendente lite*. Said motion came on to be heard in said Court before the Hon. Samuel Blatchford, circuit judge, on the nineteenth day of November, 1880, on affidavits and proofs filed by the respective parties, and was argued by counsel, to wit, Chauncey Smith and James J. Storrow, Esquires, for the complainants, and by George Harding, Esq., for the defendants; upon consideration whereof the Court did order an injunction as prayed for, restraining the defendants from infringing the said two patents of your orator, numbered 174,465 and 186,787; that such injunction issued accordingly on the twenty-second day of November, 1880; and your orator refers to a copy of the record in said suit, to be produced, and prays that the same may be made part hereof.

12. In the year 1880, the Eaton Telephone Company and its associates did infringe said patents in New York, by making and selling an electric speaking telephone apparatus, composed of a magneto telephonic receiver of a form and style called by them the "Eaton Magneto Telephone," and of a microphone battery telephonic transmitter, with carbon contacts; and did infringe said Bell patents in Massachusetts, by selling the same to others by their employé, Albert L. Spencer; whereupon your orator, the American Bell Telephone Company, brought suit against said Eaton Telephone Company and others in the United States Circuit Court in the city of New York, and against said Spencer in Boston, complaining that said defendants had hereby infringed Claim 5 of Patent 174,465, and Claims 5, 6, 8, of Patent 186,787; and said Eaton Telephone Company and their associates defended said two suits, and employed in that behalf counsel learned in the law and experts: whereupon a preliminary injunction was issued in both suits. Afterwards said suits were prepared for final hearing, and the defendants denied the validity of said patents, and denied that the use of a microphone

telephonic transmitter with carbon contacts infringed said patents; and in support of such denial and of other allegations in their answer, they introduced evidence; and among other evidence they introduced the depositions of Elisha Gray and of William M. Goodridge and of Henry Morton and of Edward S. Renwick; and the same evidence on both sides was introduced in said two suits. Said suit in Boston came on to be heard on final hearing before his Honor Judge Lowell, circuit judge at Boston, and was argued by counsel, and was, on June 27, 1881, decided by the Court in favor of the complainants; and in its said decision the Court, among other things, expressly held and decided that all the said claims of said patents sued on were good and valid claims, and that said patents were valid patents, and that the use of the kind of speaking-telephone transmitter commonly known as a microphone transmitter with carbon contacts, whereby the resistance of a battery circuit was varied by variations of pressure, due to vibrations imparted to one electrode by sound waves, infringed said fifth claim of the Bell patent 174,465. Your orator craves leave to refer to the record of said case, and to the opinion of said Court therein pronounced, and that the same may be made and deemed to be part hereof.

Also the following: —

13. A suit in the United States Circuit Court in Boston, brought in 1878 against Addison D. Hard, electrician, which resulted in a preliminary injunction; afterwards the said defendant made and exposed for sale some parts of electric speaking telephones, to the end that the purchasers thereof should complete and use the same; whereupon, after hearing, he was adjudged guilty of contempt and ordered to pay a sum of money into court, which sum was afterwards ordered to be paid and was paid to the complainant, the Bell Telephone Company. Said suit has been terminated by a final decree for the complainants.

14. A suit in the same court against Jerome C. Redding, electrician, in 1878, which resulted in a preliminary injunction and a final decree for the complainants.

15. A suit in 1878, in the United States Circuit Court in New York, against Jesse H. Bunnell, manufacturing electrician, who

appeared by counsel, and resulted in an injunction and a final decree for the complainants.

16. A suit in 1878 against Charles E. & W. H. Jones, in the United States Circuit Court in Cincinnati, wherein said defendants appeared by counsel, and in which a final decree declaring the validity of said patents, and enjoining further infringement thereof, was issued against them.

17. A suit in 1880, in the United States Circuit Court in New York, against Pearce & Jones, manufacturing electricians, in which said defendants appeared by counsel, but which resulted in a final decree declaring the validity of said patents, and enjoining further infringement thereof.

18. A suit in 1880, in the same court, against J. L. Lazelle, a manufacturer of electrical apparatus, complaining that he infringed said patents by making and selling a form of magneto telephones sometimes called "Lazelle" telephones, and a form of microphone telephonic transmitters, sometimes called the "Little Gem" transmitters; and said suit resulted in a preliminary injunction, and a final decree and perpetual injunction.

19. A suit in 1881, in the United States Circuit Court in Chicago, against Edward E. Harbert and Harbert & Co., manufacturing electricians, in which said Harbert appeared in person and a hearing was had, which resulted in a preliminary injunction, and a final decree and perpetual injunction.

20. A suit in 1881, in the same court, against the Foster Magnet Telephone Company, Gay W. Foster and others, in which the defendants appeared by counsel, and which resulted in a preliminary injunction, and a final decree establishing the validity of said patents and perpetually enjoining all further infringement thereof.

21. All said injunctions and decrees still remain in full force and effect, and all said named defendants have, so far as the complainant is informed, entirely ceased to use or sell electric speaking telephones.

22. And your orator shows that the telephones made by your said orator and the infringing telephones of the defendants are small instruments, and easily concealed, and easily used in private, and

easily transferred from one person to another, so that it is generally extremely difficult for your orator to detect all instances of such use, and extremely difficult to prove the use thereof by persons not licensed by your orator, and the extent of such use, and would be extremely onerous and burdensome for your orator to bring separate suits against each user to restrain said infringing use; and so, if the defendants, or either of them, shall be allowed to continue to manufacture and supply such instruments for use during the pendency of this suit, your orator will be wholly without adequate remedy in the premises.

23. Yet the defendants, well knowing the premises and the exclusive rights of your orator as aforesaid, but contriving to injure your orator and to deprive it of the benefit and advantage which might and otherwise would accrue to it from said inventions, without the license or consent of your orator and in infringement of the said patents, have, as your orator is informed and believes, jointly made, sold and used telephones embracing the inventions secured to your orator in said Letters Patent, or substantial and material parts of them, and have used the several improvements secured to your orator by said patents, and are still using the said several improvements at Boston and divers other places within said district, and have furnished electric speaking telephones made by them to a considerable number of persons within this district, to be connected up and used as electric speaking telephones for the transmission of articulate speech, by and according to the method secured to said Bell and to your orator by said patents, and still continue so to do; but precisely how long the defendants have made, sold and used the said several improvements, and to what extent they have made, sold and used them, your orator, for want of a discovery thereof, does not know and cannot set forth, and it prays that the defendants may be compelled to set forth the same in their answer.

And your orators have been informed and have good reason to believe and do believe as follows: Said Dolbear has constructed an electric speaking telephone apparatus, one station of which he has placed upon his own premises, 70 Washington Street, Boston, and the other station of which he has placed at the furniture warehouse of the defendant Holmes, 107 Washington Street, Boston, and still

maintains and uses the same, and he and his associates have on more than one occasion during the past three months publicly asserted and represented that they have the right to make, use and sell such instruments; and they have on more than one occasion during the past three months publicly asserted and represented that they intend to do so, and that in order the better to provide means and facilities for doing so on a large scale and extensively, they intend to organize a corporation for that purpose; that said speaking-telephone line and apparatus were by the defendants publicly exhibited to and used by large numbers of persons, partly with intent to induce such persons to become stockholders in such proposed corporation and users of similar telephones to be furnished by said defendants, and in order to aid in and promote the extensive use of such instruments; and that said assertions and representations have very recently been repeated by the defendants, and your orator verily believes that unless restrained by order of this honorable Court, the said defendants, or some of them, will at once perform some of the infringing acts which they so threaten and intend, and will perform them to such an extent as to cause great and irreparable damage to your orator.

24. Your orator has requested the said defendants to acknowledge its rights in the premises, and to desist and refrain from the said acts, and from disregarding and infringing your orator's said rights, and to account with and pay to your orator what is justly due to your orator by reason of said infringement.

25. But now so it is, may it please your Honors, that the defendants wholly refuse so to do; but on the contrary, continue and threaten to continue said infringement of the rights of your orator aforesaid, and particularly threaten to make and put out other like instruments, and thereby cause irreparable injury to your orator's lawful business: all which is contrary to equity and good conscience.

26. To the end, therefore, that the said defendants may, if they can, show why your orator should not have the relief herein prayed, and may upon their oaths, and according to their best and utmost knowledge, remembrance, information or belief, full, true, direct and perfect answer make to all and singular the matters hereinbefore stated and charged, as fully and particularly as if the same were

here repeated, and they especially interrogated as to each and every of said matters: and more especially may answer, discover and set forth, whether during any and what period of time, and whether at said Boston or elsewhere, and when and where, they used said improvements, or either of them; and whether they manufactured or sold any electric speaking telephones or apparatus to transmit speech by electricity, or the various parts of such telephones, and how many they have made or sold, and to whom they have sold the same, and how the said telephone and the several parts of the same are constructed and used; and particularly shall state whether or not they have declared and represented that they intended to furnish or cause to be furnished such telephones for use by others, and whether they have represented and declared that they intended to get up and organize a corporation for that purpose.

27. And your orator shows that it is entitled to restrain all further use of telephones which have been or shall be manufactured and disposed of by the defendants or either of them, and to receive and collect from each user thereof a suitable sum as and for damages and profits in consequence of and growing out of such use by each person who has used the same; and not waiving said rights, but wholly insisting thereon, and asserting that it intends to pursue and enforce said rights against said users, your orator avers that the defendants are also liable to pay to your orator other sums as and for profits by them actually realized by and from said infringement and unlawful acts. Wherefore your orator prays that the defendants may be decreed to account for and pay over to your orator all such gains and profits resulting to them from said infringements; and may be restrained, together with their servants and agents, by an injunction to be issued out of this honorable Court, or by one of your Honors, according to the law in such case provided, from making, selling or using the said improvements, patented as aforesaid, or either of them; and that they may also be enjoined and restrained as aforesaid during the pendency of this suit, and for such other and further relief in the premises as the nature of the case may require and to your Honors shall seem meet.

28. May it please your Honors to grant unto your orator, not only a writ of injunction, but also a writ of subpœna, to be directed

to the said defendants and each of them, commanding them and each of them, at a certain time and under a certain penalty therein to be limited, personally to be and to appear before your Honors and this honorable court, then and there to answer unto this bill of complaint, and to do and receive what to your Honors shall seem meet in the premises.

THE AMERICAN BELL TELEPHONE COMPANY,
By THEO. N. VAIL,
General Manager.

JAMES J. STORROW,
Solicitor and of Counsel.

UNITED STATES OF AMERICA,
STATE OF MASSACHUSETTS, } ss:
SUFFOLK COUNTY,

OCTOBER 20, 1881.

Personally appeared Theo. N. Vail, above named, and having been duly sworn, doth depose and say that he is general manager of said American Bell Telephone Company, and of said Bell Telephone Company; that he has read the foregoing bill and knows the contents thereof; that all the matters therein stated as to the acts of said two corporations he knows to be true; that all other matters therein stated he believes to be true; and believes the said Bell to be the true, first, and original inventor of the improvements in said two patents set forth and claimed; and that the same had not been in public use or on sale two years before his respective applications for said two patents.

Sworn to before me,

[SEAL.] GEO. WILLIS PIERCE,
Notary Public.

This cause was thence continued from term to term to the October term of this court, A. D. 1882, when, to wit, January 24, 1883, after a full hearing by the court, the Honorable Horace Gray, associate justice, and the Honorable John Lowell, circuit judge, sitting, it is ordered, adjudged, and decreed that a temporary injunction issue against the said defendants according to the prayer of the bill.

One the twenty-first day of March the following answer was filed by consent, namely:

ANSWER.

These defendants, answering so much of said bill of complaint as they are advised it is material for them to answer, jointly and severally say:

1. They admit the grant of the Letters Patent in the bill of complaint mentioned, No. 174465, dated March 7, 1876, and No. 186787, dated January 30, 1877.

2. They deny the complainants' title to said Letters Patent.

3. Electric speaking telephones had been publicly known and used long before the grant of the Bell patent of 1876; and it is matter of general knowledge among all skilled in the art that Philip Reiss invented an electric speaking telephone before 1863, which was so widely known by means of printed publications in the English language and in foreign languages that the apparatus and method of Reiss were public property in 1876 and before that year. Reiss' telephone was made public before 1870, was a matter of great interest among electricians in this country and in Europe, full and accurate knowledge of it was had by large numbers of electricians in this country and in Europe; and it was so well and widely known both in this country and in Europe that the Bell apparatus is now

and has always been considered by large numbers of electricians not as the first electric telephone, nor as the first electric speaking telephone, but merely an improved form of telephone. Before 1876 telephones, electric telephones, electric speaking telephones, and mechanical speaking telephones were so well and widely known that at the date of Bell's invention they were public property, not to be monopolized lawfully; and Bell's invention was an improvement in an old art, and was not a new art. Therefore these defendants deny all the allegations in the bill of complaint as to Bell being the first or an original invention of a new art, or of a new apparatus; and aver that his invention was nothing more than an improvement on what was well known before to all skilled in the art of telephony, including Bell himself.

4. As to acquiescence by the public these defendants admit that the public have generally recognized and acknowledged the rights of Bell and of Blake as improvers, and these defendants have and do recognize and acknowledge such rights of Bell and of Blake, but they deny that the public have ever acknowledged or recognized any right in Bell or any one else to monopolize all electric speaking telephones, no matter how constructed nor what their method of operation.

5. As to the number of Bell and Bell-Blake telephones in use, and as to the business ability and energy, and lavish, but wise expenditure, of the owners of the Bell and Blake patents, the allegations of the bill of complaint are substantially correct; but there is not now in use, and never has been in use, one speaking telephone of the kind described in the Bell patent of 1876, No. 174465; and the speaking telephone described in that patent is of no commercial value whatever, has never been made, except experimentally, is not now and has never been on sale, and is practically worthless, except as regards its scientific importance as the first embodiment of Bell's invention, namely, two coils in the same circuit, each having a core, all arranged for use according to Bell's improved method; which is controlling by the energy of the sound-waves the magnetic energy at the transmitting core, transforming that into "dynamical electricity" or current strength on the line connecting transmitter and receiver, transforming that again into magnetic energy at the receiving core, and

that finally into sound-waves; the latter sound-waves being like the first, because each new energy must correspond with the energy transformed; for it is both admitted and averred by these defendants that each and every one of the electric speaking telephones as put into use by the Bell company, or by any of the numerous infringers against whom, from time to time, suits have been brought, as alleged in the bill of complaint, or by any one else, excepting only the telephones invented by Reiss, the modifications and improvements thereof by Wright and others, and the telephones manufactured by these defendants, contained each and all of the elements first combined by Bell, namely, two coils in the same circuit, each coil having a core; means the same as or known substitutes for the means described in the Bell patent of 1876 for controlling, by the energy of the sound-waves, the magnetic energy at the transmitting coil; means the same as described in that patent for transforming that magnetic energy at the transmitting core into "dynamical electricity" on the line, precisely the same dynamical electricity and precisely the same line as described in Bell's patent of 1876; means for transforming that dynamical electricity into magnetic energy at the receiving coil, and that magnetic energy into sound-waves, all precisely as described in the Bell patent of 1876; and that Bell is the original and first inventor of this method of and apparatus for transmitting vocal and other sounds, and entitled to a patent for the same.

6. But these defendants, nevertheless, deny that Bell's patent of 1876, No. 174,465, is valid, and aver that it is wholly null and void so far as concerns electric speaking telephones. First, for the reason that the specification of said patent is not sufficient to enable any person skilled in the art or science to which the invention appertains to make, construct and use the same with practical success; secondly, because it is an attempt to patent a mere abstraction, viz., "*the employment* of a vibratory or undulatory current," regardless of the means or method for producing such a current, and also regardless of the means or method for utilizing such a current; thirdly, because it is an attempt to patent more than Bell invented, in that it is attempted to patent any and all means or methods for producing any and all electric variations conforming to the variations

of sound-waves, instead of the means or method invented by Bell for producing the electric variations new with him, and means or methods substantially the same as or known substitutes for such means or method; and in that it is attempted to patent any and all means or methods for utilizing such electric variations, instead of the means or method invented by Bell for utilizing his vibratory or undulatory current; fourthly, because it is an attempt to patent more than Bell invented, in that it is attempted to patent any and all electric variations which conform to the variations of sound-waves, not only regardless of how produced or how utilized, but also regardless of all the characteristics and qualities of such electric variations other than their conformity to sound-waves; and lastly, because in view of the state of the art of telephony, Bell invented nothing more than an improved method of and apparatus for transmitting vocal and other sound by controlling magnetic energy at the transmitter, substantially as described in his patent, by means of the energy of the sound-waves; transforming that magnetic energy into "dynamical electricity" or current strength, substantially such as is described in his patent; and utilizing such electricity at the receiver by transforming it into magnetic energy there, substantially as described in his patent; and has attempted to claim all methods of and apparatuses for transmitting vocal and other sounds by transforming at the transmitter the energy of the sound-waves into electric variations, no matter how or by what apparatus the transformation be effected, and no matter what the character or quality of the electric variations, so that they conform sufficiently to the sound-waves to be capable of producing sound-waves like the first at the receiver; and no matter how or by what apparatus these electric variations are caused to connect the receiver with the transmitter, or to produce sound-waves at the receiver.

7. These defendants aver that the following methods of and apparatus for transmitting vocal and other sounds were public property at and long before the time of Bell's invention of his improvements in the art of telephony; viz., *First*, the Reiss method and apparatus, in which the energy of the sound-waves was used at the transmitter to vary the resistance of a closed electric circuit in which was a receiver consisting of a coil which was a part of the circuit,

and a core within that coil, the method being — controlling, by the energy of the sound-waves at the transmitter, the "dynamical electricity" or current strength on the line, transforming that into magnetic energy at the receiver, and that into sound-waves. This method is inferior to Bell's method, because the energy of the sound-waves is not transformed into dynamical electricity on the line by being first transformed into magnetism; for all that causes the operation of the magneto receiver (which is the same in the Reiss and Bell methods and apparatus) is the variation in current strength of the electricity passing through the helix of the receiver, causing precisely corresponding variations in the magnetic energy of the receiving core; and practically much greater variations of current strength in the helix of the receiver can be obtained by controlling the magnetic energy of the transmitting core by the sound-waves, as in Bell's method, than by varying the current strength in the circuit directly by the sound-waves as in Reiss's method. *Second*, the Reiss method, as improved by Dr. Wright, in which the energy of the sound-waves was used at the transmitter to vary the resistance of a short electric circuit in which was a coil forming a part of the short circuit, and having a core within it; this coil and its core being within a second coil, the ends of which were connected to the plates of a condenser; this condenser being the receiver. This method was inferior to Bell's, for although the energy of the sound-waves was here utilized to vary the magnetic energy of the transmitter core, precisely as in a large majority of the telephones now made and licensed by the Bell Company, and although this varying magnetic energy at the transmitter core was transformed into electricity on the line, yet the electricity so obtained was substantially different in its action from that obtained in Bell's method by reason of the kind of receiver used in the Reiss-Wright method, which was not capable of responding alike to all variations of the electricity on the line, but responded to such as exceeded a certain electro-motive force or electric tension, head or pressure, the chief sounds emitted from the receiver being produced only when the line became so highly charged as to produce a discharge between the plates of the condenser, which was the receiver in the Reiss-Wright method; and all electrical effects other than those produced by the disruptive dis-

charge were slight, and though present were unnoticed at that time. This method was a practical and very important improvement on the Reiss method, in that it very greatly increased the loudness of the sounds given out by the receiver, by very greatly increasing the electro-motive force of the electricity on the line, and thereby correspondingly increasing the current strength utilized in the receiver. In fact, the community owes to Dr. Wright, and not to Bell or to Blake, that feature of the method now generally used, which consists in controlling the current strength of a circuit of small resistance by the energy of the sound-waves, and transforming the current strength so controlled into magnetic energy at the transmitter core; and had Dr. Wright used the Reiss-Legat receiver in the secondary circuit of his improved Reiss transmitter, viz., the Reiss transmitter in a short primary circuit of small resistance, with a core in the helix of that circuit, he would have had an electric speaking telephone not differing, except in details of construction, from the perfected form of apparatus now in general use, and the method would have been precisely the same as the perfected method now in general use; viz., using the energy of the sound-waves to control the current in a primary circuit of small resistance, transforming variations of that current into variations of magnetic energy at the core of the transmitter; these variations of magnetic energy at the transmitter core into dynamical electricity or current strength on the line; that into magnetic variations at the receiver core, and those into sound-waves like the first.

8. The Reiss telephone is an efficient electric speaking telephone, its currents are the so-called undulatory currents, and are precisely the same as one class described in the Bell patent of 1876. The Reiss-Legat telephone is an efficient electric speaking telephone, its currents are the so-called undulatory currents, precisely such as are expressly included in the Bell patent of 1876. The Reiss-Wright telephone is not a speaking telephone; but the currents in its primary circuit are the so-called undulatory currents, precisely such as are expressly included in the Bell patent of 1876; and while the electricity generated in its secondary circuit, or line wire, is substantially different from that in Bell's line, and the line of Reiss and Reiss-Legat, that arises solely because of the use of a

different receiver; and with the Reiss-Legat receiver substituted for the Wright condenser-receiver, the currents on the line would be precisely the same both in kind and degree as the currents in the line or the best form of electric speaking telephone now known; and precisely the same in kind, but far superior to, the operative currents on the line of the apparatus shown in Bell's patent of 1876.

The Reiss method is a method of transmitting vocal or other sounds telegraphically by causing electrical undulations similar in form to the vibrations of the air accompanying the said vocal or other sounds, and Bell's method is not the first method for transmitting articulate speech telegraphically.

9. The invention of Bell is an improved method or art, consisting, in comparison with Reiss's method, in varying the magnetic energy of a transmitting core by the energy of the sound-waves, transforming that into dynamical electricity or current strength on the line, being in those respects unlike Reiss's method, but in all its other steps exactly copying Reiss's method; and consisting, in view of both Reiss's method and the Reiss-Wright method, in the use of the Reiss-Wright method so far as concerns varying magnetic energy at the receiver core by the energy of the sound-waves, and the Reiss method so far as concerns transforming electrical undulations produced by variations of magnetic energy into sound-waves. Bell's patent of 1876 is valid for nothing more than a method consisting of the following steps: (1) transforming the energy of the sound-waves into variations of magnetic energy at the transmitter core (for example, directly by setting the armature of that core into vibration, as in Fig. 7 of Bell's '76 patent, or indirectly by varying an electric current passing through a helix around that core as in the Reiss-Wright method); (2) transforming the energy of these magnetic variations into dynamical electricity or current strength on the line; (3) transforming the energy of this dynamical electricity or current strength into magnetic energy at the receiver core; and (4) transforming that magnetic energy into sound-waves. Bell did not invent any one of the steps in his improved method, but each one of them was public property in 1876, and for many years before that; the first step was made public by Wright, in connection with a second

step closely analogous to, although substantially different from, Bell's second step; and the third and fourth steps of Bell's method were made public by Reiss, Gray and others, in connection with a first step closely analogous to, although substantially different from, the first step of Bell's method.

The last step of Reiss, transforming the energy of magnetic variation at the receiver into sound-waves, is precisely the same as the last step of Bell; the initial step of Reiss-Wright, varying magnetic energy at the core of the transmitter by the energy of the sound-waves, is substantially the same as the initial step of Bell; the intermediate steps in both the old methods are closely analogous to, although substantially different from, the intermediate steps in the Bell method. Bell's invention, so far as concerns apparatus, is the combination of two coils, so connected by a line of conductors that dynamical electricity produced in the line by one will be transformed into magnetic energy by going through the other, a core in each coil, and an armature for each core; and no apparatus embodies Bell's invention, or is capable of use in practising Bell's method, unless it have each of these seven elements: two coils, two cores, two armatures and a line, or equivalents or well-known substitutes for them. The Bell-Blake apparatus now in general use has these seven elements, for although it consists of (1) a short circuit with a Reiss transmitter and primary coil in it, (2) the transmitter coil, (3) the transmitter core, (4) the line, (5) the receiver coil, (6) the receiver core, (7) the receiver armature, yet the first element is a well-known substitute for the transmitter armature, and has the same duty, *i. e.*, varying the magnetic energy at the transmitter core.

10. The publications, a list of which follows, make public property in this country of the following features in methods of and apparatuses for transmitting sounds telegraphically; namely, —

As to transmitters: (1) using the energy of sound-waves to vary resistance in the main circuit; (2) using the energy of sound-waves to vary the resistance in a primary circuit, and using the energy of the primary current so varied to vary the magnetic energy at the transmitter core

As to the line: (1) transmitter and receiver forming part of a

closed circuit; (2) transmitter and receiver forming part of a circuit open as to electricity of less than a certain electro-motive force, but closed as to electricity of that electro-motive force which the generator was adapted to produce.

As to receivers: (1) using varying electrical energy on the line to vary magnetic energy at the receiver core, and that to produce sound-waves; (2) using the direct passage of a current of high tension through a non-conductor to produce sound-waves.

And the defendants aver that the alleged invention or discovery of said Bell described in said Letters Patent No. 174,465, of 1876, and the alleged invention or discovery of said Bell described in said Letters Patent No. 186,787, of 1877, had been patented and had been described in the following patents and printed publications prior to his supposed invention or discovery thereof; viz., —

(1) Letters Patent of the United States No. 166,095, dated July 27, 1875, granted to Elisha Gray.

(2) Letters Patent of the United States No. 141,777, dated August 12, 1873, granted to Thomas A. Edison and George Harrington.

(3) Letters Patent of the United States No. 156,897, dated November 17, 1874, granted to William Thomson.

(4) Letters Patent of Great Britain No. 8,345, dated January 21, 1840, granted to Charles Wheatchen.

(5) Letters Patent of Great Britain No. 2,646, dated July 29, 1874, granted to J. H. Johnson.

(6) Letters Patent of Great Britain No. 974, dated March 16, 1875, and granted to John Henry Johnson.

(7) Letters Patent of the United States No. 165,728, dated July 20, 1875, and granted to Elisha Gray.

(8) Letters Patent of the United States No. 166,094, dated July 27, 1875, and granted to Elisha Gray.

(9) Letters Patent of the United States No. 173,460, dated February 15, 1876, and granted to Elisha Gray.

(10) Letters Patent of the United States No. 173,618, dated February 15, 1876, and granted to Elisha Gray.

(11) Letters Patent of Great Britain No. 1,874, dated May 1, 1876, and granted to George Tomlinson Bonsfield.

(12) Letters Patent of the United States No. 186,340, dated January 16, 1877, and granted to Elisha Gray.

(13) Letters Patent of the Dominion of Canada No. 4,749, dated July 7, 1875, and granted to Elisha Gray.

(14) Letters Patent of the United States No. 175,971, dated April 11, 1876, and granted to Elisha Gray.

(15) "Electricity and Magnetism" by Jenkins, published in London, Eng., and New York, N. Y., in the year 1873, at page 334.

(16) "Der Elecktromagnetische Telegraph," by H. Schellen, published at Brunswick, Germany, in 1867, pages 411, 412, 413, 414, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 468 and 469.

(17) "The Electric Telegraph," by R. Sabine, published at London, Eng., in the year 1867, pages 45, 46, 136, 137 and 138.

(18) "The Electric Telegraph," by Dr. Lardner, new edition, revised by E. B. Bright, published in London, Eng., in the year 1867, at pages 164, 165, 166 and 167.

(19) "Zeitschrift des Deutsch-osterreichischen Telegraphen Verein," published at Berlin, Prussia, in the year 1862, Vol. IX., at page 125.

(20) "The Telegraphic Journal," published at said London in the year 1872, Vol. I., at page 4.

(21) "Electricity," by R. M. Ferguson, published in said London and at Edinburgh, Scotland, in the year 1867, pages 257–259.

(22) "The Telegrapher," published in New York, N. Y., in the year 1869, Vol. V., number 39, at page .

(23) "The Manufacturer and Builder," published in said New York in the year 1869, Vol. I., at page 129.

(24) "Wonders of Electricity," by J. Baile, published in said New York in the year 1872, at pages 140, 141, 142 and 143.

(25) "The Telegraphic Journal," published at said London in the year 1875, Vol. III., at pages 286, 287 and 288.

(26) "Die Fortschritte der Physik," von Dr. E. Jochmann, 1861, pages 171, 173, and 1863, page 96.

(27) "Zeitschrift of the German Austrian Telegraph Association for 1862," page 125.

(28) "Polytechnisches Journal," von Dr. E. M. Dingler, Augsburg, 1863, Nos. 168, 169, pages 23, 185 and 399.

(29) "Deutsche Klinik," No. 48, Berlin, November 28, 1863, pages 468, 469.

(30) "Deutsche Industrie Zeitung" for 1863. Chemnitz, No. 16, page 184, No. 18, page 208, and No. 22, page 249.

(31) "Frankfurter Conversationsblatt," November 29, 1861, and June 30, 1863.

(32) "Polytechnisches (Physikalisches) Centralblatt," 1863, pages 857, 859.

(33) "Polytechnisches Notizblatt," von Prof. Dr. Reed Boettger, Frankfurt a M, No. 6, XVIII., Jahrgang, 1863, pages 81, 84.

(34) "Didaskalia, Blaetter fur Geist, Gemueth and Publicitaet," September 28, 1864, No. 232.

(35) "Die Gartenlaube," Leipsic, 1863, No. 51, page 807.

(36) "Transactions Royal Scottish Society of Arts," Edinburgh, Vol. VI., 1864, appendix Q, pages 184, 187.

(37) "Annual Report of American Association for the Advancement of Science" for 1869.

(38) "Die Neueren Apparate der Akoustik," von Fr. Pisko, Wien 1865, pages 94 *et seq.*

(39) Ditto, pages 241 *et seq.*

(40) "Jahresbericht des Physikalishen Vereins, Frankfurt a M," for the year 1860–1861, pages 57–64.

11. The fifth claim of Bell's patent of 1876 is void if construed to cover all methods of transmitting vocal or other sounds by the use of electricity, because it is not for an art, machine, manufacture or composition of matter, or any improvement on either, but for a mere abstraction, viz., causing certain electrical undulations vaguely described, and having no other limitation than similarity in form to the vibrations of the air accompanying vocal or other sounds, regardless of the method of causing such electrical undulations, regardless of the method of utilizing them, regardless of whether they be undulations in a closed line of conductors, or in an open line of conductors, or in a non-conductor; regardless whether they be undulations of "dynamical electricity," that is, undulations in the strength of the current, which actuates the receiver; or whether they be undulations of

charge or static electricity, that is, variations in the density of the electricity which actuates the receiver; or whether they be undulations of charge such as would exist in a non-conductor (say a glass plate) were a charged diaphragm vibrated by the voice in its neighborhood.

This 5th claim is also void, because causing electrical undulations is in itself, and without regard to the method of causing and the method of using them, of mere scientific interest, and wholly lacking in all requisites of a patentable subject.

This 5th claim is also void, because the electric undulations mentioned are not properly described, it being impossible to say whether they exist or not unless the means or method of causing them be known, or unless their presence be proved by the work done by them, or both.

This 5th claim is also void, because not limited to the only thing susceptible of invention or discovery, viz., the method of causing certain undulations and the method of utilizing them; for if these undulations be new (which is denied), they are worthless unless an appropriate method for causing and for utilizing them be described; and any one may lawfully either cause them or utilize them, or both, so long as he does not appropriate any invention or discovery properly patented.

This 5th claim is also void, because the art of transmitting vocal and other sounds is not susceptible of invention or discovery; for all that can be invented or described is certain means or certain methods whereby that end can be accomplished; and causing electrical undulations without more is neither a method of nor apparatus for transmitting sounds; but any method of transmitting sounds by electricity must include some method of causing the sounds to be transmitted to fit electricity for its duty, and must also include some method of causing this electricity to do its duty at the point to which the sounds are to be transmitted, that is, must include a transmitting method, a receiving method, and some sort of a channel or medium by which the electricity fitted for its work by the transmitting method may reach the place where its work is to be done, and all this was perfectly well known long before any invention or discovery of Bell, as it is a mere statement of the essential condi-

tions of the problem of the transmission of speech by electricity, and is not the subject of invention or discovery.

12. These defendants have never been concerned in the manufacture or sale of telephones embracing the inventions or either of them, or any substantial or material parts of either of them, described in either of the patents mentioned in the bill of complaint; but they admit the manufacture and use of telephones invented by the defendant Dolbear and described in his Letters Patent No. 239,742, dated April 5, 1881; No. 240,578, dated April 26, 1881; and aver that they have full right to manufacture, use and sell such telephones, and that they are radically different in all substantial respects from any invention described in either of the said Bell patents. The transmitter used in the Dolbear telephone is in all material respects identical with the Reiss-Wright transmitter. It is a Reiss transmitter in a circuit of small resistance, having a helix as a part of it, with the transmitting core in that helix; the line is an open circuit, and is the first open circuit ever used for any practical purpose, and it was wholly unknown until Dolbear's discovery that such a line was capable of any practical use. The receiver is wholly new, wholly unlike any prior instrument, and operates upon a principle never before applied in any of the useful arts. The method invented by Dolbear, and the only method practised when his apparatus is used, is precisely the same as the Reiss-Wright method so far as concerns the use of the energy of the sound-waves to vary the electric current in a circuit of small resistance, and the use of the current so varied to vary the magnetic energy of the transmitter core; but is wholly new with Dolbear in all other respects, for the magnetic variations of the transmitter core must be converted into electric variations of many times greater electro-motive force than any ever before utilized for any practical purpose, and must be generated in a line whose resistance is practically infinite, and must be transformed directly into sound-waves. Dolbear's method is his own discovery and invention, is radically different from all other methods of transmitting sounds, except as to its first step, which is the same as that of the Reiss-Wright method, and is of the highest value and importance, inasmuch as it remedies fully some very serious faults in the Bell method, which was the best known before Dolbear's discovery.

And these defendants pray the same benefit of the facts and things herein set forth as if for the reason thereof they had demurred to said bill, where a demurrer would have been proper, and the same benefit thereof as if they had specially pleaded to the said bill, where a special plea would have been proper.

Wherefore these defendants submit that the complainants are not entitled to the relief, or any part thereof, prayed for in said bill of complaint; without this, that any other matter in said bill contained, material to be answered unto, and not herein sufficiently answered unto, confessed and avoided, traversed or denied, is true.

All which matters and things these defendants are ready to aver, maintain and prove as this Honorable Court shall direct; and pray to be hence dismissed with their reasonable costs and charges in this behalf most wrongfully sustained.

AMOS E. DOLBEAR,
HENRY B. METCALF,
FRANCIS M. HOLMES,
By J. E. MAYNADIER,
their Solicitor.

CAUSTEN BROWNE,
of Counsel.

DISTRICT OF MASSACHUSETTS.

SUFFOLK, ss. BOSTON, March 15, 1883.

Then personally appeared the above-named Amos E. Dolbear, and made oath that he has read the above answer; that he understands the contents thereof, and that the statements therein are true, as stated. Before me,

WILLIAM A. COPELAND,
Notary Public.

[SEAL]

And on the thirtieth day of March the following replication was filed, namely:

Replication.

The replication of the above-named complainants to the answer of the defendants above named.

These repliants, saving and reserving unto themselves all and all manner of advantage of exception to the manifest insufficiencies of the said answer, for replication thereunto, say:

That they will aver and prove their said bill to be true, certain, and sufficient in the law to be answered unto; and that the said answer of the defendants is uncertain, untrue, and insufficient to be replied unto by these repliants, without this, that any other matter or thing whatever in the said answer contained, material or effectual in the law to be replied unto, confessed, and avoided, traversed, or denied, is true. All which matters and things these repliants are and will be ready to aver and prove as this honorable court shall direct, and humbly pray as in and by their said bill they have already prayed.

By their attorney, JAMES J. STORROW.

This cause was thence continued to this present term, when publication of the testimony having passed in the clerk's office, this cause is set down for hearing and fully heard by the court, the Honorable John Lowell, circuit judge, sitting, on the thirtieth day of June, 1883, on the 25th day of August, 1883, the opinion of the court is announced, and on the eighth day of September, 1883, the following decree is entered, namely:

Final Decree.

This cause came on to be heard at this present term upon the pleadings and proofs, and was argued by counsel for the respective parties; and now, upon consideration thereof, to wit, Sept. 8th, 1883, it is ordered, adjudged, and decreed as follows, viz., that the letters patent referred to in the complainants' bill, being letters patent of the United States, granted unto Alexander Graham Bell, No. 174465, for improvement in telegraphy, dated March 7th, 1876, is a good and valid patent; and that the said Alexander Graham Bell was the original and first inventor of the improvement described and claimed therein; and that the said defendants have infringed the fifth claim of said patent and upon the exclusive rights of the complainants under the same.

And it appearing to the court that the complainants waive a reference to a master to take an account of the profits and damages, and that the parties agree that the amount of profits and damages to be recovered by the complainants be fixed at the sum of one hundred dollars, it is further ordered that the complainants recover the said sum of one hundred dollars accordingly.

And it is further ordered, adjudged, and decreed that a perpetual injunction be issued under said patent No. 174465 against the defendants according to the prayer of the bill. The court has not considered letters patent No. 186787, dated January 30th, 1877, in the bill mentioned.

And it is further ordered, adjudged, and decreed that the complainants recover of the defendants its costs of suit taxed at ——.

From this decree the defendants in open court claim an appeal to the Supreme Court of the United States, and give good and sufficient security that they will prosecute their said appeal to effect and answer all damages and costs if they fail to make their plea good, and said appeal is allowed accordingly.

A true record,

Attest: JOHN G. STETSON, *Clerk.*

The following is the evidence used in the hearing of said cause before said circuit court, namely:

EVIDENCE FOR COMPLAINTS.

CIRCUIT COURT OF THE UNITED STATES, *District of Massacausetts*, } *ss:*

No. 1628.

In Equity.

AMERICAN BELL TELEPHONE COMPANY
v.
AMOS E. DOLBEAR, *et al.*

Proofs for Final Hearing, taken in Pursuance of the Sixty-Seventh Rule as amended. Before me,

WILLIAM A. COPELAND,
Special Examiner.

Present: J. J. STORROW, Esq., *for Complainants.*
J. E. MAYNADIER, Esq., *for Defendants.*

Complainants introduce assignments of the Bell patents named in the bill as follows:

COMPLAINANTS' EXHIBIT—ASSIGNMENT BELL TO HUBBARD.

ASSIGNMENT OF PATENT RIGHT.

Liber R[21], p. 399.

To all whom it may concern.

Whereas, Alexander Graham Bell, of Boston, in the county of Suffolk, and State of Massachusetts, did obtain three several Letters Patent of the United States for an improved system of telegraphy, telephony, and telephonic apparatus, which Letters Patent bear date respectively, March seventh, A. D. eighteen hundred and seventy-six, and numbered 174465; June sixth, A. D. eighteen

hundred and seventy-six, and numbered 178,399; and January thirtieth, A. D. eighteen hundred and seventy-seven, and numbered 186,787.

And whereas, Gardiner G. Hubbard, of Cambridge, in the county of Middlesex and State of Massachusetts, trustee, is desirous of acquiring an interest therein; now this indenture witnesseth that for a valuable consideration, viz., one dollar and other valuable consideration to me in hand paid, the receipt of which is hereby acknowledged, I have assigned, sold and set over, and by these presents do assign, sell and set over unto the said Gardiner G. Hubbard, trustee, all the right, title and interest I have in the above-described invention, as secured to me by Letters Patent, for, to and in the United States and Territories, and in no other place or places. The same to be held and enjoyed by the said Gardiner G. Hubbard, trustee, for his own use and behoof, and for the use and behoof of his legal representatives, to the full end of the term for which said letters were granted, as fully and entirely as the same would have been held and enjoyed by me had this assignment and sale not been made.

In testimony whereof, I have hereunto set my hand and affixed my seal this day of July, in the year of our Lord one thousand eight hundred and seventy-seven.

ALEXANDER GRAHAM BELL. [SEAL]

Sealed and delivered in presence of

CHAS. EUSTIS HUBBARD.

Recorded July 28, 1877.

COMPLAINANTS' EXHIBIT ASSIGNMENT HUBBARD TO BELL TELEPHONE COMPANY.

ASSIGNMENT OF PATENT RIGHT.

Liber Y^{n}, p. 460.

To all whom it may concern:—

Whereas, Alexander Graham Bell, of Salem, Massachusetts, as assignor to himself, Thomas Sanders and Gardiner G. Hubbard, did obtain Letters Patent of the United States, bearing date April 6, 1875, and numbered 161,739; and whereas said Alexander Graham

Bell did obtain Letters Patent of the United States, bearing date March 7, 1876, and numbered 174,465; bearing date June 6, 1876, and numbered 178,399; and bearing date Jan. 30, 1877, and numbered 186,787, all of said Letters Patent being for improvements in "Telegraphy, Telephony, and Telephonic Apparatus" invented by said Alexander Graham Bell; and whereas, all of said Letters Patent have been assigned to Gardiner G. Hubbard, trustee, said letters numbered 161,739, by deed of assignment, delivered July 9, 1877, and recorded in Liber T[21], page 448 of Transfers of Patents; and said letters numbered 174,465, 178,399 and 186,787, by deed of assignment, delivered July 9, 1877, and recorded Liber R[21], page 399 of Transfers of Patents; and said Hubbard, trustee, is now the owner of the above-described inventions secured by said Letters Patent; and whereas the Bell Telephone Company, a corporation duly established under the laws of the Commonwealth of Massachusetts, and located at Boston, is desirous of acquiring the ownership of said inventions secured by said Letters Patent.

Now, this indenture witnesseth that I, Gardiner G. Hubbard, trustee, in consideration of one dollar and other valuable consideration to me in hand paid by said Bell Telephone Company, the receipt whereof is hereby acknowledged, have assigned, sold and set over, and by these presents do assign, sell and set over unto the said Bell Telephone Company all my right, title and interest in the above-described inventions and in and to said Letters Patent, each and all of them, the same to be held and enjoyed by the said Bell Telephone Company for its own use and behoof, and for the use and behoof of its legal representatives, to the full end of the term for which said letters were granted, and any extension or reissue thereof, as fully and entirely as the same would have been held and enjoyed by me had this assignment and sale not been made.

In testimony whereof, I have hereunto set my hand and seal this twentieth day of July, in the year eighteen hundred and seventy-eight, being thereto duly authorized.

GARDINER G. HUBBARD, *Trustee.* [SEAL]

In presence of

C. E. HUBBARD.

R. W. DEVONSHIRE.

COMPLAINANTS' EXHIBIT ASSIGNMENT BELL TELEPHONE COMPANY TO AMERICAN BELL TELEPHONE COMPANY.

Liber B[27], p. 101.

Know all men by these presents, That the Bell Telephone Company, a corporation created under the laws of the Commonwealth of Massachusetts, in consideration of one dollar and other valuable considerations to it paid by the American Bell Telephone Company, a corporation created under said laws, the receipt whereof is hereby acknowledged, does hereby grant and convey unto said American Bell Telephone Company the exclusive right under the following patents to the State of Massachusetts, viz.: Letters Patent No. 174,465, issued March 7, 1876, to Alexander Graham Bell for an improvement in telegraphy, and Letters Patent No. 186,787, issued January 30, 1877, to said Bell for an improvement in electric telegraphy and in and to the inventions therein described or intended to be described; and does further grant, assign and convey to said American Bell Telephone Company any and all other right, title and interest now remaining to it, said Bell Telephone Company, in, to and under said Letters Patent and inventions.

To have and to hold the same to the said American Bell Telephone Company, its successors and assigns, to their own use and behoof forever.

This instrument is made at the request of the National Bell Telephone Company in pursuance of an agreement between said Bell Telephone Company and said National Bell Telephone Company, dated March 20, 1879, said American Bell Telephone Company being the appointee of said National Bell Telepone Company to receive this conveyance, and in pursuance of an agreement between said National Bell Telephone Company and said American Bell Telephone Company, dated May 8, 1880.

In witness whereof, said Bell Telephone Company has caused its corporate seal to be hereto affixed and these presents to be signed in its name and behalf by W. H. Forbes, its president, thereto duly authorized, this twenty-third day of April, A. D. 1881.

[Seal of B. T. Co.] (Signed) THE BELL TELEPHONE COMPANY,
By W. H. FORBES, *Pres't.*

Received for record, July 6, 1881, and recorded in Liber B[27], page 101 of Transfers of Patents.

In testimony whereof, I have caused the seal of the Patent Office to be hereunto affixed.

[Seal of Patent Office.] E. M. MARBLE.

Ex'd. F. C. T.

COMPLAINANTS' EXHIBIT CHARTER AMERICAN BELL TELEPHONE COMPANY.

Chapter 117.

COMMONWEALTH OF MASSACHUSETTS.

IN THE YEAR ONE THOUSAND EIGHT HUNDRED AND EIGHTY.

AN ACT to Incorporate the American Bell Telephone Company.

Be it enacted by the Senate and House of Representatives, in General Court assembled, and by the authority of the same, as follows: —

SECTION 1. Alexander Graham Bell, William H. Forbes, George Z. Silsbee, Richard S. Fay, Alexander Cochrane, George L. Bradley, Francis Blake, Jr., Thomas Sanders, and Charles Eustis Hubbard, and their associates, may associate themselves and organize a corporation, according to the provisions of chapter two hundred and twenty-four of the acts of the year eighteen hundred and seventy, and the acts in amendment thereof and addition thereto, for the purpose of manufacturing, owning, selling, using and licensing others to use electric speaking telephones and other apparatus and appliances pertaining to the transmission of intelligence by electricity, and for that purpose constructing and maintaining by itself and its licensees public and private lines and district exchanges, with a capital stock exceeding one million of dollars and not exceeding ten millions of dollars.

SECTION 2. For the purposes aforesaid, said corporation may become a stockholder in, or become interested with other corporations hereafter organized for like purposes, or already established for the transaction of telephonic business under its patents and no others: provided, that said corporation shall not become a stockholder in any other corporation doing business in this State to an

amount exceeding thirty per cent of the capital stock of said last-named corporation. And it and its licensees may, within this Commonwealth, enjoy the rights given by chapter sixty-four of the General Statutes and acts amendatory thereof, and shall be subject to the liabilities therein imposed; but section ten of said chapter shall only apply to their public lines; and the apportionment provided by section five of chapter two hundred and eighty-three of the acts of the year eighteen hundred and sixty-five, and acts amendatory thereof, shall be made upon the number of telephones in use by it, or under its authority, or with its permission, or under Letters Patent owned or controlled by it, within and without this Commonwealth, respectively; and the returns to be made under said act shall state the facts required for such apportionment in such form as the tax commissioner may determine; and it shall be the duty of said tax commissioner, or his deputy, to annually examine the books, accounts and papers of said corporation, so far as may be necessary for the verification of said returns.

SECTION 3. When an injury is done to a person or to property by the posts, wires, telephones or other apparatus of the corporation, caused by any negligence on the part of itself or its officers, or on the part of any of its agents, servants, employés or operatives, the corporation shall be responsible in damages to the party injured.

SECTION 4. The franchise or charter of said corporation shall not be sold or offered for sale, or leased to any company, or to any person or association of persons, without the consent of the legislature; and any contract made contrary to the provisions of this act shall be void. And this charter may be revoked by the legislature for any cause which they deem sufficient.

SECTION 5. The provisions of the first and second sections of the three hundred and tenth chapter of the acts of the year eighteen hundred and sixty-eight shall apply to said telephone company and its licensees. Said corporation shall be subject to all general laws that now are, or that may be hereafter in force, relating to similar corporations, so far as the same shall not be inconsistent with the provisions of this act.

SECTION 6. This act shall take effect upon its passage.

HOUSE OF REPRESENTATIVES, March 12, 1880.

Passed to be enacted.

CHARLES J. NOYES, *Speaker.*

IN SENATE, March 17, 1880.

Passed to be enacted.

ROBERT R. BISHOP, *President.*

March 19, 1880. Approved.

JOHN D. LONG.

SECRETARY'S DEPARTMENT, BOSTON, March 19, 1880.

A true copy.

Witness the seal of the Commonwealth.

[SEAL] HENRY B. PEIRCE,

Secretary of the Commonwealth.

COMPLAINANTS' EXHIBIT CERTIFICATE OF INCORPORATION AMERICAN BELL TELEPHONE COMPANY.

No. 1,077.

COMMONWEALTH OF MASSACHUSETTS.

Be it known that whereas W. H. Forbes, George L. Bradley, G. Z. Silsbee, Charles Eustis Hubbard, Francis Blake, W. G. Saltonstall, Richard S. Fay, R. W. Devonshire, Charles Emerson, Thomas B. Bailey and C. M. Whitcomb have associated themselves with the intention of forming a corporation under the name of the American Bell Telephone Company, for the purpose of manufacturing, owning, selling, using and licensing others to use electric speaking telephones, and other apparatus and appliances pertaining to the transmission of intelligence by electricity, and for that purpose constructing and maintaining, by itself and licensees, public and private lines and district exchanges, with a capital of seven million three hundred and fifty thousand dollars, and have complied with the provisions of the statutes of this Commonwealth in such case made and provided, as appears from the certificate of the President, Treasurer, and Directors of said corporation, duly approved by the Commissioner of Corporations, and recorded in this office: —

Now, therefore, I, Henry B. Peirce, Secretary of the Commonwealth of Massachusetts, do hereby certify that said W. H. Forbes,

G. L. Bradley, G. Z. Silsbee, C. E. Hubbard, F. Blake, W. G. Saltonstall, R. S. Fay, R. W. Devonshire, C. Emerson, T. B. Bailey and C. M. Whitcomb, their associates and successors, are legally organized and established, as and are hereby made an existing corporation under the name of the American Bell Telephone Company, with the powers, rights and privileges, and subject to the limitations, duties and restrictions, which by law appertain thereto.

Witness my official signature hereunto subscribed, and the seal of the Commonwealth of Massachusetts hereunto affixed this seventeenth day of April, in the year of our Lord one thousand eight hundred and eighty.

(Signed) HENRY B. PEIRCE,

[SEAL] *Secretary of the Commonwealth.*

COMMONWEALTH OF MASSACHUSETTS.

SECRETARY'S DEPARTMENT, BOSTON, Oct. 13, 1880.

I hereby certify that the foregoing is a true copy of the certificate of incorporation of the American Bell Telephone Company, organized under the provisions of chapter two hundred and twenty-four, of the acts of the year eighteen hundred and seventy, and chapter one hundred and seventeen, of eighteen hundred and eighty, having "the force and effect of a special charter," as appears by the record of this department.

Witness the seal of the Commonwealth.

HENRY B. PEIRCE,

[SEAL] *Secretary of the Commonwealth.*

Copy of the last clause of Section 11, *of Chapter* 224, *of the Acts of the year eighteen hundred and seventy.*

"The Secretary of the Commonwealth shall sign the same, and cause the seal of the Commonwealth to be thereto affixed, and such certificate shall have the force and effect of a special charter, and be conclusive evidence of the organization and establishment of such corporation. The Secretary shall also cause a record of such certificate to be made, and a copy of such record, duly certified, may, with like effect as the original certificate, be given in evidence to prove the organization and establishment of such corporation."

COMMONWEALTH OF MASSACHUSETTS.

SECRETARY'S DEPARTMENT, BOSTON, Oct. 18, 1880.

I hereby certify that the foregoing is a true copy of the last clause of Section 11, of Chapter 224, of 1870, and is now in force; and that the certified copies of record hereto annexed are the copies in said section referred to.

In testimony whereof, witness my hand and the seal of the Commonwealth hereto affixed.

HENRY J. COOLIDGE,

[SEAL] *Deputy Secretary of the Commonwealth.*

STIPULATION.

It is admitted by the defendants that they have made and used speaking telephone apparatus composed of instruments the same as the instruments now produced, marked "Dolbear Transmitter," "Dolbear Receiver No. 1," "Dolbear Receiver No. 2."

The parties have agreed as follows by stipulation on file: —

It is agreed that the affidavits and evidence heretofore filed in this case upon motion for preliminary injunction shall stand as final proofs in the cause; neither party desire that the witnesses shall be called for cross examination.

The affidavits and proofs referred to in said stipulation are the following: —

Sheet 1.

7, 1876.

2 Sheets

A. G. BELL.

TELEGRAPHY.

Patented March

Fig. 1.

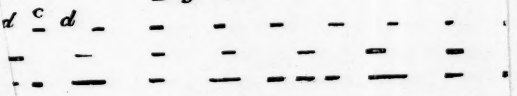


Fig. 2.

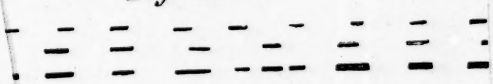


Fig. 3

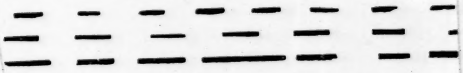
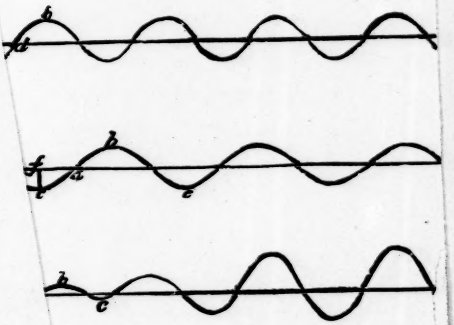


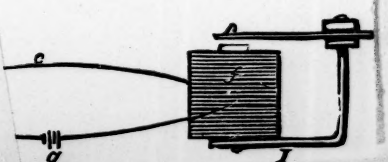
Fig. 4.



B

A. B

Fig. 5.



COMMONWEALTH OF MASSACHUSETTS.

SECRETARY'S DEPARTMENT, BOSTON, Oct. 18, 1880.

I hereby certify that the foregoing is a true copy of the last clause of Section 11, of Chapter 224, of 1870, and is now in force; and that the certified copies of record hereto annexed are the copies in said section referred to.

In testimony whereof, witness my hand and the seal of the Commonwealth hereto affixed.

HENRY J. COOLIDGE,

[SEAL] *Deputy Secretary of the Commonwealth.*

STIPULATION.

It is admitted by the defendants that they have made and used speaking telephone apparatus composed of instruments the same as the instruments now produced, marked "Dolbear Transmitter," "Dolbear Receiver No. 1," "Dolbear Receiver No. 2."

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2 Sheets—Sheet 1.

A. G. BELL.

TELEGRAPHY.

No. 174,465. Patented March 7, 1876.

Fig. 1.

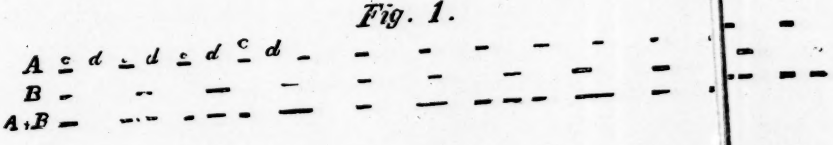


Fig. 2.

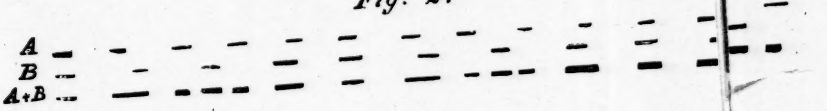


Fig. 3

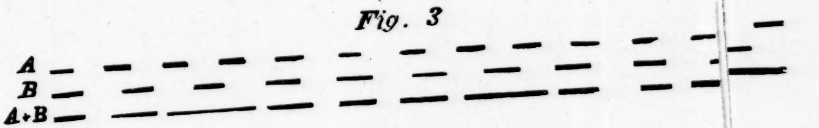


Fig. 4.

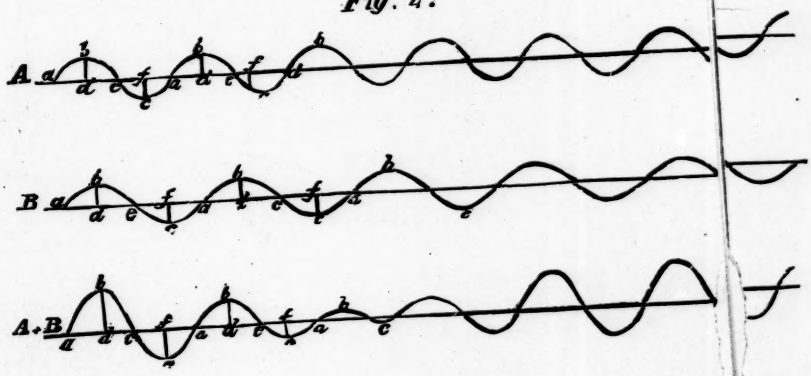
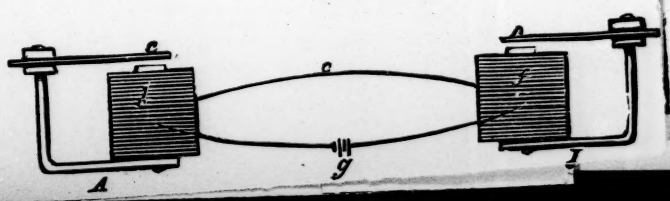


Fig. 5.



2 Sheets—Sheet 2

A. G. BELL.

TELEGRAPHY

No. 174,465. Patented March 7, 1876.

Fig. 6.

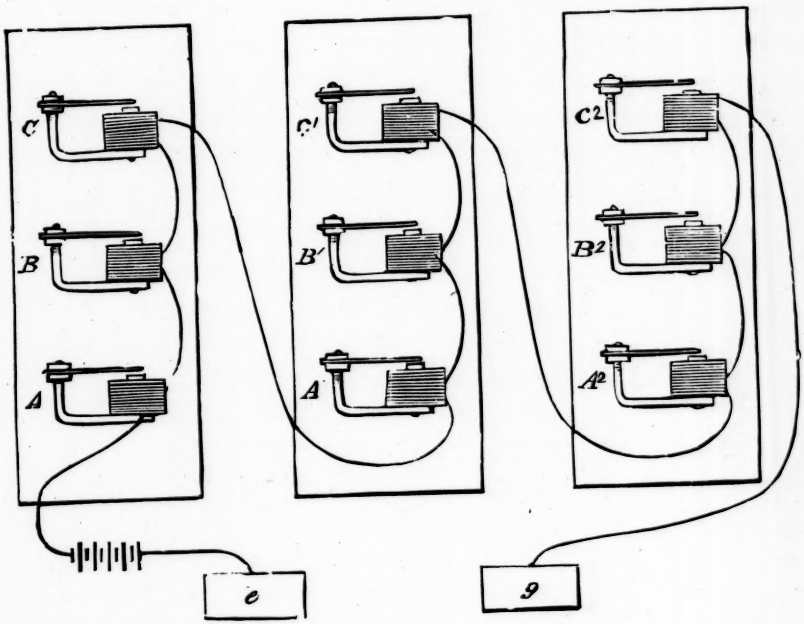
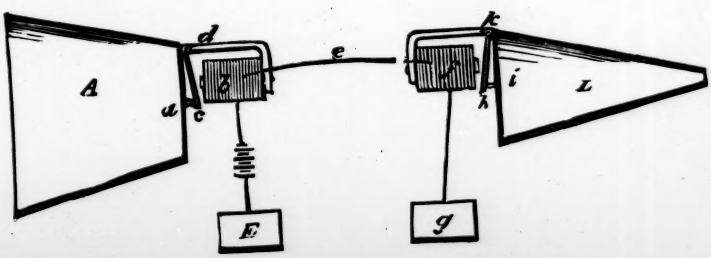


Fig. 7



UNITED STATES PATENT OFFICE.

ALEXANDER GRAHAM BELL, OF SALEM, MASSACHUSETTS.

IMPROVEMENT IN TELEGRAPHY.

Specification forming part of Letters Patent No. 174,465, dated March 7, 1876; application filed Febuary 14, 1876.

To all whom it may concern:

Be it known that I, ALEXANDER GRAHAM BELL, of Salem, Massachusetts, have invented certain new and useful Improvements in Telegraphy, of which the following is a specification: —

In Letters Patent granted to me April 6, 1875, No. 161,739, I have described a method of, and apparatus for, transmitting two or more telegraphic signals simultaneously along a single wire by the employment of transmitting instruments, each of which occasions a succession of electrical impulses differing in rate from the others; and of receiving instruments, each tuned to a pitch at which it will be put in vibration to produce its fundamental note by one only of the transmitting instruments; and of vibratory circuit-breakers operating to convert the vibratory movement of the receiving instrument into a permanent make or break (as the case may be) of a local circuit, in which is placed a Morse sounder, register, or other telegraphic apparatus. I have also therein described a form of autograph-telegraph based upon the action of the above-mentioned instruments.

In illustration of my method of multiple telegraphy I have shown in the patent aforesaid, as one form of transmitting instrument, an electro-magnet having a steel-spring armature, which is kept in vibration by the action of a local battery. This armature in vibrating makes and breaks the main circuit, producing an intermittent current upon the line-wire. I have found, however, that upon this plan the limit to the number of signals that can be sent simultaneously over the same wire is very speedily reached; for, when a number of transmitting instruments, having different rates of vibration, are simultaneously making and breaking the same circuit, the

effect upon the main line is practically equivalent to one continuous current.

In a pending application for Letters Patent, filed in the United States Patent Office Feburary 25, 1875, I have described two ways of producing the intermittent current — the one by actual make and break of contact, the other by alternately increasing and diminishing the intensity of the current without actually breaking the circuit. The current produced by the latter method I shall term, for distinction sake, a pulsatory current.

My present invention consists in the employment of a vibratory or undulatory current of electricity in contradistinction to a merely intermittent or pulsatory current, and of a method of, and apparatus for, producing electrical undulations upon the line-wire.

The distinction between an undulatory and a pulsatory current will be understood by considering that electrical pulsations are caused by sudden or instantaneous changes of intensity, and that electrical undulations result from gradual changes of intensity exactly analogous to the changes in the density of air occasioned by simple pendulous vibrations. The electrical movement, like the aerial motion, can be represented by a sinusoidal curve or by the resultant of several sinusoidal curves.

Intermittent or pulsatory and undulatory currents may be of two kinds, accordingly as the successive impulses have all the same polarity or are alternately positive and negative.

The advantages I claim to derive from the use of an undulatory current in place of a merely intermittent one are, first, that a very much larger number of signals can be transmitted simultaneously on the same circuit; second, that a closed circuit and single main battery may be used; third, that communication in both directions is established without the necessity of special induction-coils; fourth, that cable despatches may be transmitted more rapidly than by means of an intermittent current or by the methods at present in use; for, as it is unnecessary to discharge the cable before a new signal can be made, the lagging of cable-signals is prevented; fifth, and that as the circuit is never broken a spark-arrester becomes unnecessary.

It has long been known that when a permanent magnet is caused

to approach the pole of an electro-magnet a current of electricity is induced in the coils of the latter, and that when it is made to recede a current of opposite polarity to the first appears upon the wire. When, therefore, a permanent magnet is caused to vibrate in front of the pole of an electro-magnet an undulatory current of electricity is induced in the coils of the electro-magnet, the undulations of which correspond, in rapidity of succession, to the vibrations of the magnet, in polarity to the direction of its motion, and in intensity to the amplitude of its vibration.

That the difference between an undulatory and an intermittent current may be more clearly understood I shall describe the condition of the electrical current when the attempt is made to transmit two musical notes simultaneously — first upon the one plan and then upon the other. Let the interval between the two sounds be a major third; then their rates of vibration are in the ratio of 4 to 5. Now, when the intermittent current is used the circuit is made and broken four times by one transmitting instrument in the same time that five makes and breaks are caused by the other. A and B, Figs. 1, 2, and 3, represent the intermittent currents produced, four impulses of B being made in the same time as five impulses of A. *c c c*, &c., show where and for how long time the circuit is made, and *d d d*, &c., indicate the duration of the breaks of the circuit. The line A and B shows the total effect upon the current when the transmitting instruments for A and B are caused simultaneously to make and break the same circuit. The resultant effect depends very much upon the duration of the make relatively to the break. In Fig. 1 the ratio is as 1 to 4; in Fig. 2, as 1 to 2; and in Fig. 3 the makes and breaks are of equal duration. The combined effect, A and B, Fig. 3, is very nearly equivalent to a continuous current.

When many transmitting instruments of different rates of vibration are simultaneously making and breaking the same circuit the current upon the main line becomes for all practical purposes continuous.

Next, consider the effect when an undulatory current is employed. Electrical undulations, induced by the vibration of a body capable of inductive action, can be represented graphically, without error, by the same sinusoidal curve which expresses the vibration of the

inducing body itself, and the effect of its vibration upon the air; for, as above stated, the rate of oscillation in the electrical current corresponds to the rate of vibration of the including body — that is, to the pitch of the sound produced. The intensity of the current varies with the amplitude of the vibration — that is, with the loudness of the sound; and the polarity of the current corresponds to the direction of the vibrating body — that is, to the condensations and rarefactions of air produced by the vibration. Hence, the sinusoidal curve A or B, Fig. 4, represents, graphically, the electrical undulations induced in a circuit by the vibration of a body capable of inductive action.

The horizontal line *a d e f*, &c., represents the zero of current. The elevations *b b b*, &c., indicate impulses of positive electricity. The depressions *c c c*, &c., show impulses of negative electricity. The vertical distance *b d* or *c f* of any portion of the curve from the zero-line expresses the intensity of the positive or negative impulse at the part observed, and the horizontal distance *a a* indicates the duration of the electrical oscillation. The vibrations represented by the sinusoidal curves B and A, Fig. 4, are in the ratio aforesaid, of 4 to 5 — that is, four oscillations of B are made in the same time as five oscillations of A.

The combined effect of A and B, when induced simultaneously on the same circuit, is expressed by the curve A+B, Fig. 4, which is the algebraical sum of the sinusoidal curves A and B. This curve A+B also indicates the actual motion of the air when the two musical notes considered are sounded simultaneously. Thus, when electrical undulations of different rates are simultaneously induced in the same circuit, an effect is produced exactly analogous to that occasioned in the air by the vibration of the inducing bodies. Hence, the co-existence upon a telegraphic circuit of electrical vibrations of different pitch is manifested, not by the obliteration of the vibratory character of the current, but by peculiarities in the shapes of the electrical undulations, or, in other words, by peculiarities in the shapes of the curves which represent those undulations.

There are many ways of producing undulatory currents of electricity, dependent for effect upon the vibrations or motions of bodies capable of inductive action. A few of the methods that may be

employed I shall here specify. When a wire, through which a continuous current of electricity is passing, is caused to vibrate in the neighborhood of another wire, an undulatory current of electricity is induced in the latter. When a cylinder, upon which are arranged bar-magnets, is made to rotate in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet.

Undulations are caused in a continuous voltaic current by the vibration or motion of bodies capable of inductive action; or by the vibration of the conducting-wire itself in the neighborhood of such bodies. Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit, or by alternately increasing and diminishing the power of the battery. The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery, therefore, occasions an undulatory action in the voltaic current. The external resistance may also be varied. For instance, let mercury or some other liquid form part of a voltaic circuit, then the more deeply the conducting-wire is immersed in the mercury or other liquid, the less resistance does the liquid offer to the passage of the current. Hence, the vibration of the conducting-wire in mercury or other liquid included in the circuit occasions undulations in the current. The vertical vibrations of the elements of a battery in the liquid in which they are immersed produces an undulatory action in the current by alternately increasing and diminishing the power of the battery.

In illustration of the method of creating electrical undulations, I shall show and describe one form of apparatus for producing the effect. I prefer to employ for this purpose an electro-magnet, A, Fig. 5, having a coil upon only one of its legs *b*. A steel-spring armature, *c*, is firmly clamped by one extremity to the uncovered leg *d* of the magnet, and its free end is allowed to project above the pole of the covered leg. The armature *c* can be set in vibration in a variety of ways, one of which is by wind, and, in vibrating, it produces a musical note of a certain definite pitch.

When the instrument A is placed in a voltaic circuit, *g b e f g*,

the armature *c* becomes magnetic, and the polarity of its free end is opposed to that of the magnet underneath. So long as the armature *c* remains at rest, no effect is produced upon the voltaic current, but the moment it is set in vibration to produce its musical note a powerful inductive action takes place, and electrical undulations traverse the circuit *g b e f g*. The vibratory current passing through the coil of the electro-magnet *f* causes vibration in its armature *h* when the armature *c h* of the two instruments A I are normally in unison with one another; but the armature *h* is unaffected by the passage of the undulatory current when the pitches of the two instruments are different.

A number of instruments may be placed upon a telegraphic circuit, as in Fig. 6. When the armature of any one of the instruments is set in vibration all the other instruments upon the circuit which are in unison with it respond, but those which have normally a different rate of vibration remain silent. Thus, if A, Fig. 6, is set in vibration, the armatures of A^1 and A^2 will vibrate also, but all the others on the circuit will remain still. So if B^1 is caused to emit its musical note the instruments B B^2 respond. They continue sounding so long as the mechanical vibration of B^1 is continued, but become silent with the cessation of its motion. The duration of the sound may be used to indicate the dot or dash of the Morse alphabet, and thus a telegraphic dispatch may be indicated by alternately interrupting and renewing the sound. When two or more instruments of different pitch are simultaneously caused to vibrate, all the instruments of corresponding pitches upon the circuit are set in vibration, each responding to that one only of the transmitting instruments with which it is in unison. Thus the signals of A, Fig. 6, are repeated by A^1 and A^2, but by no other instrument upon the circuit; the signals of B^2 by B and B^1; and the signals of C^1 by C and C^2 — whether A, B^2, and C^1 are successively or simultaneously caused to vibrate. Hence by these instruments two or more telegraphic signals or messages may be sent simultaneously over the same circuit without interfering with one another.

I desire here to remark that there are many other uses to which these instruments may be put, such as the simultaneous transmission

of musical notes, differing in loudness as well as in pitch, and the telegraphic transmission of noises or sounds of any kind.

When the armature *c*, Fig. 5, is set in vibration the armature *h* responds not only in pitch but in loudness. Thus, when *c* vibrates with little amplitude, a very soft musical note proceeds from *h*; and when *c* vibrates forcibly the amplitude of the vibration of *h* is considerably increased, and the resulting sound becomes louder. So, if A and B, Fig. 6, are sounded simultaneously, (A loudly and B softly,) the instruments A^1 and A^2 repeat loudly the signals of A, and B^1 B^2 repeat softly those of B.

One of the ways in which the armature *c*, Fig. 5, may be set in vibration has been stated above to be by wind. Another mode is shown in Fig. 7, whereby motion can be imparted to the armature by the human voice or by means of a musical instrument.

The armature *c*, Fig. 7, is fastened loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, and its other extremity is attached to the centre of a stretched membrane, *a*. A cone, A, is used to converge sound-vibrations upon the membrane. When a sound is uttered in the cone the membrane *a* is set in vibration, the armature *c* is forced to partake of the motion, and thus electrical undulations are created upon the circuit E *b e f g*. These undulations are similar in form to the air vibrations caused by the sound — that is, they are represented graphically by similar curves. The undulatory current passing through the electro-magnet *f* influences its armature *h* to copy the motion of the armature *c*. A similar sound to that uttered into A is then heard to proceed from L.

In this specification the three words "oscillation," "vibration," and "undulation," are used synonymously, and in contradistinction to the terms "intermittent" and "pulsatory." By the term "body capable of inductive action," I mean a body which, when in motion, produces dynamical electricity. I include in the category of bodies capable of inductive action — brass, copper, and other metals, as well as iron and steel.

Having described my invention, what I claim, and desire to secure by Letters Patent, is as follows:

1. A system of telegraphy in which the receiver is set in vibra-

tion by the employment of undulatory currents of electricity, substantially as set forth.

2. The combination, substantially as set forth, of a permanent magnet or other body capable of inductive action, with a closed circuit, so that the vibration of the one shall occasion electrical undulations in the other, or in itself, and this I claim, whether the permanent magnet be set in vibration in the neighborhood of the conducting-wire forming the circuit, or whether the conducting-wire be set in vibration in the neighborhood of the permanent magnet, or whether the conducting-wire and the permanent magnet both simultaneously be set in vibration in each other's neighborhood.

3. The method of producing undulations in a continuous voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration or motion of the conducting-wire itself, in the neighborhood of such bodies, as set forth.

4. The method of producing undulations in a continuous voltaic circuit by gradually increasing and diminishing the resistance of the circuit, or by gradually increasing and diminishing the power of the battery, as set forth.

5. The method of, and apparatus for, transmitting vocal or other sounds telegraphically, as herein described, by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sounds, substantially as set forth.

In testimony whereof I have hereunto signed my name this 20th day of January, A. D. 1876.

ALEX. GRAHAM BELL.

Witnesses:

THOMAS E. BARRY,

P. D. RICHARDS.

2 Sheets—Sh

A. G. BELL.

ELECTRIC TELEGRAPHY.

Patented Jan. 30,

No. 186,787.

Fig. 1.

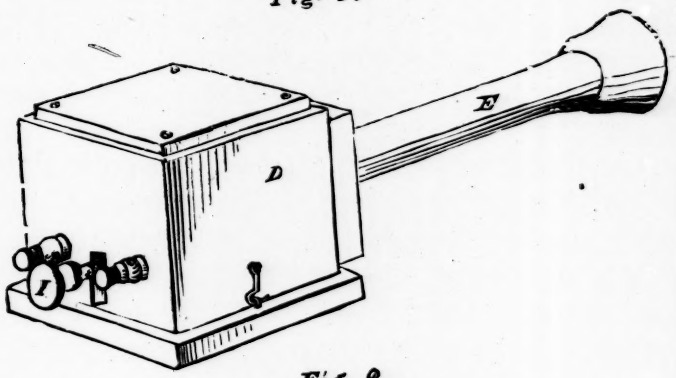


Fig. 2.

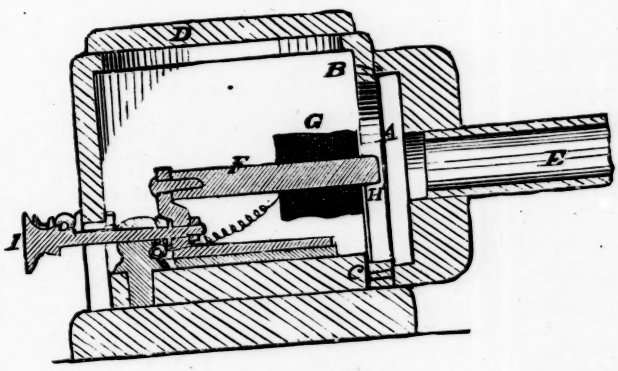
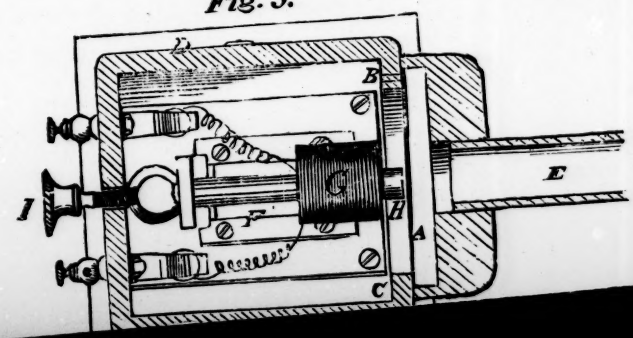


Fig. 3.



2 Sheets—Sheet 2.

A. G. BELL.

ELECTRIC TELEGRAPHY.

No. 186,787. Patented Jan. 30, 1877.

Fig. 4.

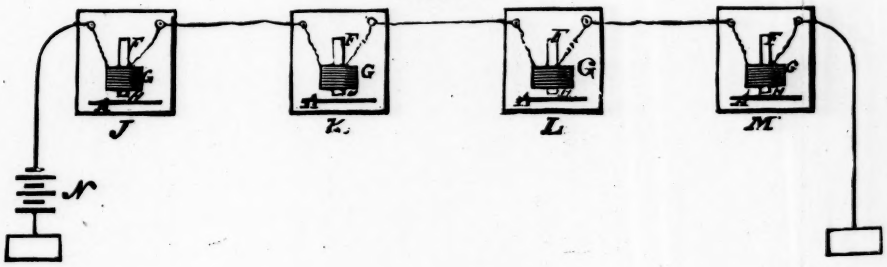


Fig 5.

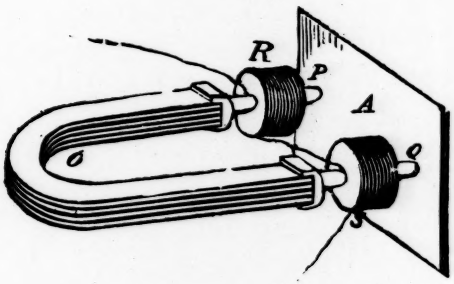
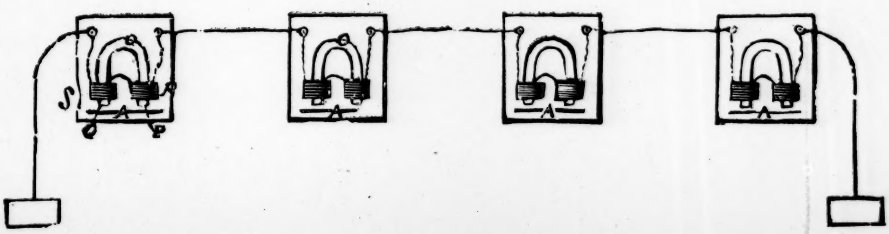


Fig. 6.



UNITED STATES PATENT OFFICE.

ALEXANDER GRAHAM BELL, OF BOSTON, MASSACHUSETTS.

IMPROVEMENT IN ELECTRIC TELEGRAPHY.

Specification forming part of Letters Patent No. 186,787, dated January 30, 1877; application filed January 15, 1877.

To all whom it may concern:

Be it known that I, ALEXANDER GRAHAM BELL, of Boston, Massachusetts, have invented certain new and useful Improvements in Electric Telephony, of which the following is a specification:

In Letters Patent granted to me the 6th day of April, 1875, No. 161,739, and in an application for Letters Patent of the United States now pending, I have described a method of and apparatus for producing musical tones by the action of a rapidly-interrupted electrical current, whereby a number of telegraphic signals can be sent simultaneously along a single circuit.

In another application for Letters Patent now pending in the United States Patent Office I have described a method of and apparatus for inducing an intermittent current of electricity upon a line-wire, whereby musical tones can be produced and a number of telegraphic signals be sent simultaneously over the same circuit, in either or in both directions; and in Letters Patent granted to me March 7, 1876, No. 174,465, I have shown and described a method of an apparatus for producing musical tones by the action of undulatory currents of electricity, whereby a number of telegraphic signals can be sent simultaneously over the same circuit, in either or in both directions, and a single battery be used for the whole circuit.

In the applications and patents above referred to, signals are transmitted simultaneously along a single wire by the employment of transmitting-instruments, each of which occasions a succession of electrical impulses differing in rate from the others, and are received without confusion by means of receiving-instruments, each tuned to

a pitch at which it will be put in vibration to produce its fundamental note by one only of the transmitting-instruments. A separate instrument is therefore employed for every pitch, each instrument being capable of transmitting or receiving but a single note, and thus as many separate instruments are required as there are messages or musical notes to be transmitted.

My invention has for its object, first, the transmission simultaneously of two or more musical notes or telegraphic signals along a single wire in either or both directions, and with a single battery for the whole circuit without the use of as many instruments as there are musical notes or telegraphic signals to be transmitted; second, the electrical transmission by the same means of articulate speech and sound of every kind, whether musical or not; third, the electrical transmission of musical tones, articulate speech, or sounds of every kind, without the necessity of using a voltaic battery.

In my Patent No. 174,465, dated March 7, 1876, I have shown as one form of transmitting-instrument a stretched membrane, to which the armature of an electro-magnet is attached, whereby motion can be imparted to the armature by the human voice, or by means of a musical instrument, or by sounds produced in any way.

In accordance with my present invention I substitute for the membrane and armature shown in the transmitting and receiving instruments alluded to above a plate of iron or steel capable of being thrown into vibration by sounds made in its neighborhood.

The nature of my invention and the manner in which the same is or may be carried into effect will be understood by reference to the accompanying drawings, in which —

Figure 1 is a perspective view of one form of my electric telephone. Fig. 2 is a vertical section of the same, and Fig. 3 is a plan view of the apparatus. Fig. 4 is a diagram illustrating the arrangement upon circuit.

Similar letters in the drawings represent corresponding portions of the apparatus.

A in said drawings represents a plate of iron or steel, which is fastened at B and C to the cover or sounding-box D. E represents a speaking-tube, by which sounds may be conveyed to or from the

plate A. F is a bar of soft iron. G is a coil of insulated copper wire, placed around the extremity of the end H of the bar F. I is an adjusting-screw, whereby the distance of the end H from the plate A may be regulated.

The electric telephones J, K, L, and M are placed at different stations upon a line, and are arranged upon circuit with a battery, N, as shown in diagram, Fig. 4.

I have shown the apparatus in one of its simplest forms, it being well understood that the same may be varied in arrangement, combination, general construction, and form, as well as material of which the several parts are composed.

The operation and use of this instrument are as follows:

I would premise by saying that this instrument is and may be used both as a transmitter and as a receiver — that is to say, the sender of the message will use an instrument in every particular identical in construction and operation with that employed by the receiver, so that the same instrument can be used alternately as a receiver and a transmitter.

In order to transmit a telegraphic message by means of these instruments, it is only necessary for the operator at a telephone (say J) to make a musical sound in any way in the neighborhood of the plate A — for convenience of operation, through the speaking-tube E — and to let the duration of the sound signify the dot or dash of the Morse alphabet, and for the operator who receives his message (say at M) to listen to his telephone, preferably through the speaking-tube E. When two or more musical signals are being transmitted over the same circuit all the telephones reproduce the signals for all the messages; but as the signals for each message differ in pitch from those for the other messages, it is easy for an operator to fix his attention upon one message and ignore the other.

When a large number of despatches are being simultaneously transmitted it will be advisable for the operator to listen to his telephone through a resonator, which will re-enforce to his ear the signals which he desires to observe. In this way he is enabled to direct his attention to the signals for any given message without

being distracted or disturbed by the signals for any other messages that may be passing over the line at the time.

The musical signals, if preferred, can be automatically received by means of a resonator, one end of which is closed by a membrane, which vibrates only when the note with which the resonator is in unison is emitted by the receiving-telephone. The vibrations of the membrane may be made to operate a circuit-breaker, which will actuate a Morse sounder or a telegraphic recording or registering apparatus.

One form of vibratory circuit-breaker which may be used for this purpose I have described in Letters Patent No. 178,399, June 6, 1876. Hence by this plan the simultaneous transmission of a number of telegraphic messages over a single circuit in the same or in both directions with a single main battery for the whole circuit and a single telephone at each station is rendered practicable. This is of great advantage in this, that for the conveyance of several messages, or signals, or sounds over a single wire simultaneously, it is no longer necessary to have separate instruments correspondingly tuned for each given sound, which plan requires nice adjustment of the corresponding instruments, while the present improvement admits of a single instrument at each station, or, if for convenience several are employed, they all are alike in construction, and need not be adjusted or tuned to particular pitches.

Whatever sound is made in the neighborhood of any telephone — say at J, Fig. 4 — is echoed in fac-simile by the telephones of all the other stations upon the circuit; hence this plan is also adapted for the use of the transmitting intelligibly the exact sounds of articulate speech. To convey an articulate message it is only necessary for an operator to speak in the neighborhood of his telephone, preferably through the tube E, and for another operator at a distant station upon the same circuit to listen to the telephone at that station. If two persons speak simultaneously in the neighborhood of the same or different telephones, the utterances of the two speakers are reproduced simultaneously by all the other telephones on the same circuit; hence by this plan a number of vocal messages may be transmitted simultaneously on the same circuit, in either or both directions. All the effects noted above may be produced by the

same instruments without a battery by rendering the central bar F H permanently magnetic. Another form of telephone for use without a battery is shown in Fig. 5, in which O is a compound permanent magnet, to the poles of which are affixed poll-pieces of soft iron, P Q, surrounded by helices of insulated wire R S.

Fig. 6 illustrates the arrangement upon circuits of similar instruments to that shown in Fig. 5.

In lieu of the plate A in above figures, iron or steel reeds of definite pitch may be placed in front of the electro-magnet O, and, in connection with a series of such instruments of different pitches, an arrangement upon circuit may be employed similar to that shown in my Patent No. 174,465, and illustrated in Fig. 6 of Sheet 2 in said patent. The battery, of course, may be omitted.

This invention is not limited to the use of iron or steel, but includes within its scope any material capable of inductive action.

The essential feature of the invention consists in the armature of the receiving-instrument being vibrated by the varying attraction of the electro-magnet so as to vibrate the air in the vicinity thereof in the same manner as the air is vibrated at the other end by the production of the sound. It is, therefore, by no means necessary or essential that the transmitting-instrument should be of the same construction as the receiving-instrument. Any instrument receiving and transmitting the impression of agitated air may be used as the transmitter, although, for convenience and for reciprocal communication, I prefer to use like instruments at either end of an electrical wire. I have heretofore described and exhibited such other means of transmitting sound, as will be seen by reference to the proceedings of the American Academy of Arts and Sciences, Volume XII.

For convenience, I prefer to apply to each instrument a call-bell. This may be arranged so as to ring, first, when the main circuit is opened; second, when the bar F comes into contact with the plate A. The first is done to call attention; the second indicates when it is necessary to readjust the magnet, for it is important that the distance of the magnet from the plate should be as little as possible, without, however, being in contact. I have also found that the electrical undulations produced upon the main line by the vibration of the plate A are intensified by placing the coil G at the end of the

bar F nearest the plate A, and not extend it beyond the middle, or thereabout.

Having thus described my invention, what I claim, and desire to secure by Letters Patent, is—

1. The union upon, and by means of, an electric circuit of two or more instruments, constructed for operation substantially as herein shown and described, so that, if motion of any kind or form be produced in any way in the armature of any one of the said instruments, the armatures of all the other instruments upon the same circuit will be moved in like manner and form, and if such motion be produced in the former by sound, like sound will be produced by the motion of the latter.

2. In a system of electric telegraphy or telephony, consisting of transmitting and receiving instruments united upon an electric circuit, the production, in the armature of each receiving-instrument, of any given motion by subjecting said armature to an attraction varying in intensity, however such variation may be produced in the magnet; and hence I claim the production of any given sound or sounds from the armature of the receiving-instrument by subjecting said armature to an attraction varying in intensity, in such manner as to throw the armature into that form of vibration that characterizes the given sound or sounds.

3. The combination, with an electro-magnet, of a plate of iron or steel, or other material capable of inductive action, which can be thrown into vibration by the movement of surrounding air or by the attraction of a magnet.

4. In combination with a plate and electro magnet, as before claimed, the means herein described, or their mechanical equivalents, of adjusting the relative position of the two so that, without touching, they may be set as closely together as possible.

5. The formation, in an electric telephone such as herein shown and described, of a magnet with a coil upon the end or ends of the magnet nearest the plate.

6. The combination, with an electric telephone such as described, of a sounding-box, substantially as herein shown and set forth.

7. In combination with an electric telephone, as herein described,

the employment of a speaking or hearing tube for conveying sounds to or from the telephone, substantially as set forth.

8. In a system of electric telephony, the combination of a permanent magnet with a plate of iron or steel, or other material capable of inductive action, with coils upon the end or ends of said magnet nearest the plate, substantially as set forth.

In testimony whereof I have hereunto signed my name this 13th day of January, A. D. 1877.

A. GRAHAM BELL.

Witnesses:

HENRY R. ELLIOTT,

EWELL A. DICK.

AFFIDAVIT OF ALEXANDER GRAHAM BELL.

I, Alexander Graham Bell, on oath depose and say: —

I am the patentee named in the patents of the United States, No. 174,465, dated March 7, 1876, and 186,787, dated Jan. 30, 1877. I know that I am an original, and I verily believe that I am the first, inventor of the inventions set forth and claimed in those two patents.

My father was a teacher of articulation; and as he intended that I should follow his own profession, I very early became acquainted with the researches of Helmholtz relating to the "quality" of sounds, and made some discoveries 1
of my own relating to this subject. I also, before 1870, made a considerable study of electricity with a view to the telegraphic transmission of sounds, and constructed apparatus for this purpose. My studies, experiments and inventions in both these directions continued and absorbed most of my attention, broken chiefly by my duties in the Boston School for the Deaf, and elsewhere, in instructing the deaf and dumb to articulate. I also, in 1873, 1874 and 1875, devoted a good deal of time, study and experiment to the vibration of stretched membranes by vocal and other 2
sounds, with a view to utilize the fact that the vibratory motions compelled in them by the utterance of such sounds conformed not merely in frequency but in "form" and "character" to the form and character of the aerial vibrations which constitute such sounds.

The possibility of the transmission of articulate speech telegraphically had long been in my mind, and in 1874 I devised a plan which, theoretically at least, would accomplish this. It embodied the principle of the magneto transmitter and receiver, shown in Fig. 7 of my patent, 3
174,465, of March 7, 1876, and was in effect the same as those instruments, each having a magnet, and an armature attached to a membrane, to be used as there described. In

October, 1874, I described this to Dr. Clarence J. Blake (lecturer on Otology in Harvard University and aural surgeon at the Massachusetts Eye and Ear Infirmary), and illustrated by description by drawings made on the spot. I did not then construct the apparatus, because I was not sure that the currents generated by that method would be
4 strong enough to be of practical utility.

In March, 1875, I explained some of my inventions to Prof. Henry at Washington; and in a letter which I wrote March 18, 1875, describing that interview, I said: —

"Such a chimerical ideaa as telegraphing vocal sounds would, indeed, to most minds, seem scarcely feasible enough to spend time in working over. I believe, however, that it is feasible, and that I have got the cue to the solution of the problem."

Fearing, at that time, that the magneto currents gener-
5 ated by an instrument like the transmitter of Fig. 7 of my said patent, 174,465, would be too weak, I conceived that a proper way to obtain stronger currents and effects would be to use the constant power of a strong battery, and utilize the vibrations given to the transmitter by the voice to vary the resistance of the circuit through which the current from that battery passed. With reference to this plan, I wrote in a letter, May, 4, 1875: "If this turns out to be the case, the oscillations of the current should correspond in *amplitude* as well as in the rate of movement to the vibra-
6 tions of the string. One consequence would be that the *timbre* of a sound could be transmitted. The plan for transmitting *timbre*, that I explained to you before, — viz., causing permanent magnets to vibrate in front of electromagnets, — is chiefly defective on account of the feebleness of the induced currents. If the other plan is successful, the strength of the current can be increased *ad libitum*, without destroying the *relative intensities of the vibrations*."

In a letter of May 24, 1875, I wrote: "Every moment of my time is devoted to study of electricity and to ex-
7 periments. The subject broadens. I think that the transmission of the human voice is much more nearly at hand

than I had supposed. . . . I fear that this telegraphic business may force me to remain the greater portion of the summer here; but I cannot tell yet, so many details have to be worked out. My inexperience in such matters is a great drawback. However, Morse conquered his electrical difficulties, though he was only a painter; and I don't intend to give in either, till all is completed."

Before this time I had perfectly satisfied myself that the true and only method for the telegraphic transmission of 8
vocal sounds involved as its fundamental element an apparatus which should transmit amplitude or intensity as well as pitch, — for "quality" or *timbre* or articulation were ultimately resolvable into these two characteristics of vibration, — and therefore that the electrical transmission of speech depended upon producing upon the line wire electrical undulations or variations which should correspond in form to the aerial vibrations which constituted the sound to be transmitted; and I perceived that a circuit-breaking 9
apparatus (such, for example, as the Reis transmitter) was necessarily totally inadequate to do this, because it merely tended to intermit the current, and not to control it, — to govern its changes as to frequency, but not as to intensity, or form, or character. I was aiming to perfect an apparatus which should carry out my method in two ways; one by varying the electro-motive force in a circuit of constant resistance, and the other by varying the resistance in a circuit supplied with a constant electro-motive force. I intended to do both of these by means of a vibrational move-
ment taken up by stretched membranes or elastic metals 10
when spoken to.

In my description given to Dr. Clarence J. Blake, in October, 1874, I had described a working apparatus intended to produce these electrical undulations when spoken to, by varying the electro-motive force. My only doubt about this apparatus was purely electrical and practical; viz., whether currents generated by such slight movements of a thin armature would be sufficiently strong to produce audible effects at the receiving station. On June 2, 1875, in the

11 course of some experiments, I discovered that slight movements of a thin armature would produce currents of available strength. This at once removed the last supposed difficulty from my mind, and the electrical speaking telephone became to me a completed discovery and a fixed fact. I announced this to one of my friends in a letter written on that day, in which I used the following language: "I have succeeded to-day in transmitting signals *without any battery whatever!* The musical note produced at the receiving end was sensibly the equivalent of that at the transmit-
12 ting end in *loudness* as well as pitch."

I continued the experiment in question for several hours, and I confess with some excitement in what I felt was the realization of my hopes and the completion of a great invention; before I left the room I directed Mr. Watson, my assistant, to make an apparatus with a stretched membrane, in accordance with directions I then gave him, and which substantially conformed to the description I had given Dr. Blake in October, 1874. The instrument was at once made, and soon after another like it. These were
13 electric speaking telephones, substantially the same as those of Fig. 7 of my patent 174,465, and were capable of transmitting and reproducing articulate speech.

In the autumn of 1875 I drew the specification for my patent 174,465, but the application was delayed in order to arrange for funds with persons who, I was led to believe, would take an interest and assist me. I had not sufficient means myself.

My specification was sent to Washington on Jan. 9, 1876. It was examined there by Mr. A. Pollok, the patent
14 solicitor who was to take charge of it. He had a fair copy made by his clerk and sent to me Jan. 18, 1876. This copy differed from the specification which I sent Jan. 9, only by a few changes purely verbal in their character. It was sworn to by me in Boston, Jan. 20, 1876, and filed in the Patent Office, Feb. 14, 1876.

I have read the affidavit of Mr. Watson in this case; and the statements in it with regard to my recognition as the

inventor of the electric speaking telephone and with regard to its introduction into public use, are correct.

I will add that Professor T. Sterry Hunt was among those present at the exhibition of my electric speaking telephone at the Centennial, June 25, 1876, and a few hours afterwards I received from him the following note: —

"Continental Hotel, Phila., June 25, 1876.

"Dear Mr. Bell: — I am informed that you leave to-night for Boston, so I take this way of congratulating you on your success to-day. I returned to my hotel with Sir Wm. Thomson, and dined with him. He speaks with much enthusiasm of your achievement. What yesterday he would have declared impossible, he has to-day seen realized, and he declares it the most wonderful thing he has seen in America. You speak of it as an embryo invention, but to him it seems already complete; and he declares that, before long, friends will whisper their secrets over the electric wire.

"Your undulating current he declares a great and happy conception.

"All this he discussed partly with Dr. Bache, and more at length with Sir Redmond Barry and Sir John Hawkshaw. Sir William leaves here on Friday for Montreal, and will visit Boston for a day or two before sailing, which will be from New York, July 19.

"Thinking you would be glad to hear the judgment of one so eminent, I have written you this, and I am, my dear Mr. Bell,

"Always truly yours,

"T. Sterry Hunt.

"P. S. — Do you know anything of Brücher's system of visible speech, of which one of the Austrian judges spoke to-day? It seems very like your father's.

"Graham Bell, Esq."

The exhibition of Jan. 13, 1877, was at the Medical College at Washington, before the Philosophical Society of

Washington. I was assisted in it by E. N. Dickerson, Esq., and Professor Henry presided.

I have stated very briefly the time at which, and the manner in which, my invention was made and was reduced to practice. The letters from which I have given extracts,
19 and a much fuller account of the whole matter, will be found in my direct examination and cross examination, as a witness in the suit, Bell Telephone Company *et al. v.* Dowd, to which I refer. In that suit, Dr. Clarence J. Blake testified as a witness, and identified the drawings and repeated the description which I gave him in October, 1874.

I verily believe, also, that I am the first and original inventor of the inventions set forth and claimed in my patent 186,787, dated Jan. 30, 1877 For a fuller state-
20 ment of the origin of said inventions, I refer to my said deposition and to the depositions of Mr. Watson and Mr. Wilson, in said suit of Bell Telephone Company *et al. v.* Dowd.

Sworn to. ALEXANDER GRAHAM BELL.

AFFIDAVIT OF CHARLES R. CROSS FOR COMPLAINANTS.

My name is Charles R. Cross; age, thirty-two; I reside in Boston, Massachusetts, and am the Thayer Professor of Physics at the Massachusetts Institute of Technology, Boston.

I have been acquainted with the electric speaking telephone since the early part of 1876. I have studied the subject extensively and made a number of experiments relating to it. I have read Mr. A. G. Bell's two patents, No. 174,465, dated March 7, 1876, and No. 186,787, dated Jan. 30, 1877, and understand them and the inventions therein described. I have frequently used electric speaking telephones made in accordance with them. 1

In order to a better understanding of those patents, it will be advisable for me to say something of the subject matter to which they relate.

The sensation of sound is caused by the action upon the ear of the vibrating particles of air set into a to-and-fro motion by a sound-producing body. When a given sound is produced, all these particles have the same character of motion: but as the motion is communicated from one to the other, the motion of two successive particles at the same instant is not identical, because the one lags a little behind the other in its changes; and this causes them to be alternately huddled together and more widely separated, producing along any line in space alternate condensations and rarefactions. These alternate condensations and rarefactions are called sound waves. If the requisite motion be imparted to one air particle, the elasticity of the atmosphere will cause this motion to be imparted to particle after particle, and sound waves will result. 2 3

As the condensations and rarefactions of the air are caused by the motions of the particles and their relative velocities, all the changes and variations in the one correspond and conform in their character to the changes and

70

variations of each of the others. It will therefore be sufficient to consider the motion of one air particle, the means of producing that motion, and the effect of that motion on bodies with which the particle comes in contact.

In these sound vibrations each particle has an extremely
4 minute to-and-fro motion in the line of propagation of the sound. The particle, starting from a position of rest, passes to the farther extremity of its path, back to the position of rest, then swings beyond it to the other extremity of its path, thence returns, and so continues to vibrate to and fro until some impeding cause brings it to rest.

The vibrations of this particle may present three kinds of difference: first, in the extent of its path from the extreme limit on one side to the extreme limit on the other; second, in the frequency with which it passes over its en-
5 tire path and returns to any point; third, in the character of its motion while passing from one extremity of the path to the other. *E. g.*, though its motion is always to and fro along one straight line, yet it may move with a speed which varies at every instant, and the character of this variation may change at each instant; its motion while passing from one end of its path to the other may be continuous in one direction, or it may move onward a little at one speed, and backward a little at another, and still reach the same limit of its path at the same instant: in fact, the character of its
6 motion is susceptible of infinite variations, though all its movements are executed to and fro in the same straight line. Other things being the same, the distance apart of the extreme limits of its path determines its loudness, the frequency with which it passes from one extreme limit to the other determines what the ear recognizes as the pitch of the sound produced, while the character of its motion in passing from one extremity to the other determines what is called the character or quality of the sound.

"Quality" is the difference which distinguishes from
7 each other, sounds which the ear recognizes as different, even though they may be of the same pitch and loudness; as, for example, the note of a violin from that of a flute

or of the human voice, one voice from another, one vowel sound from another, one syllable from another. For sounds in general, including all articulate sounds, though recognized by the ear as having a definite pitch, are yet composed of several notes sounded simultaneously and differing from each other both in pitch and in intensity and loudness.

These partial tones, the combination of which affects the 8
ear as a single sound, consists of one lowest note, called the *fundamental*, and others of a higher pitch, often as many as twelve or sixteen, which are called *overtones*. The pitch which the ear recognizes as that of the whole sound is not the mean of the pitches of all the notes; it is simply that of one predominant note, which (except in a few special cases) is the lowest, or fundamental. The other partials are not recognized by the ear as affecting the pitch of the sound; they have a different function; they determine the character, "quality" or *timbre* of the sound heard. For 9
this character or quality depends upon the number and pitch of the various overtones, and the relative intensity of each; that is, depends, so to speak, upon the ingredients which are combined with the fundamental, and the amount of each which enters into the combination. These variations in the number, pitch and relative intensity of the overtones, upon which the character or "quality" of the sound depends, are themselves immediately determined by the various differences in the character of the motion of the vibrating particle while passing from one end of its 10
path to the other, as already explained.

In order to reproduce articulate speech, or any other sound having quality, it is therefore necessary to produce a vibratory movement of the air particle, which, in the *character* of its motion, as well as in the frequency with which it performs its total vibration, shall correspond to the particular sound desired.

If we determine the speed and direction of motion of the particle at each successive instant, we shall determine the character of its motion; if we compel it at each 11

successive instant to move with the desired speed, and in the desired direction, we shall control the character of its motion, and shall compel it to produce the desired sound.

The complete theory of the quality of articulate and other sounds, as here stated, was first demonstrated by Helmholtz as early as 1863, and is very commonly known as Helmholtz's theory of quality.

The method of reproducing vocal and other sounds, shown by Mr. Bell in his specification 174,465, consists in
12 utilizing the sound waves or motions of the air particles produced by the speaker at the transmitting station to move a diaphragm there placed, whose motion in turn serves to vary the electrical condition of the line wire leading to the receiver and the parts in circuit with it; and these electrical variations compel the diaphragm of the receiving instrument at each instant to take up the same character of motion, which, in turn, it imparts to the particles of air in contact with it, thus producing at the receiving station a sound which is a copy of that produced
13 by the voice of the speaker at the transmitting station.

According to his specification, he embodies that method in a transmitter, some part of which takes up from the air the motion given to the air particles by the voice of the speaker, and vibrates in exact accordance with them; a receiver, a part of which reproduces the vibrations of the transmitter, though generally with diminished intensity, and imparts them to the air particles at the receiving station; and a line wire which connects the two, and affords an uninterrupted passage for the currents of
14 electricity, the character of which and the variations in which are determined by the motion in the transmitter, and in turn determine the motion in the receiver.

In this apparatus, the function of the transmitter was to receive from the vibration of the air particles a vibrational movement of the same character as that of the particles or sound waves themselves; by the motion so taken up, to cause upon the line wire electrical undulations or variations of current corresponding in character, as well as

in frequency, to these motions. The function of the line wire was to convey these electrical undulations to the re- 15
ceiving instrument; while the function of the receiver was to produce a vibrational movement of a diaphragm by these electrical undulations, and thereby to produce vibrational motion of the adjacent air, by causing these electrical undulations to set up in the diaphragm of the receiver vibrational motions which, in character, as well as in frequency, correspond to the electrical undulations, and therefore to the movement in the transmitter which produced them. By this method, the air at the receiving station is compelled to copy the vibrations produced in the air at 16
the transmitting station by the voice of the speaker, and a sound precisely similar to that uttered at one end of the apparatus is heard at the other.

Thus the sound which is the result at the receiving end is precisely similar to the sound which is the cause at the transmitting end.

It may be true that the receiver does not always reproduce the motions of the transmitter in every possible minute variation; but the instrument will be a speaking telephone only so far as in principle it is adapted to reproduce them 17
with accuracy, and in construction is so far perfect that it will reproduce them with substantial fidelity. Moreover, the variations between the sound waves which constitute a given articulate sound, and those which constitute a sound not recognizable as articulate speech, are such, that an excessively minute departure from the theoretical requirements will substantially deprive the instrument of all practical value.

Mr. Bell's method and apparatus described in his patent 174,465 involves the use of and consists of three instru- 18
ments: a transmitter at the sending or speaking station, a receiver at the receiving or listening station, and a line wire which connects the two in an unbroken circuit.

His specification 174,465 shows in Fig. 7 an apparatus, the receiving portion of which contains a diaphragm capable of being vibrated at varying rates, with varying amplitude, and with vibrational movements of substan-

tially any character concerned in the production of sound, using the word "character" in the sense in which I have
19 defined it. It is provided with an inductive armature attached to the diaphragm, and placed in front of an electromagnet, which is kept continuously magnetized by a battery current passing through its coils.

This magnet draws the diaphragm towards itself with a power proportioned to its strength, and the strength of the magnet at each instant depends upon the strength of the current passing over the line from the transmitter to the receiver; it is therefore the strength of this current at each instant which controls the position of the diaphragm.
20 Every variation in its strength causes a change of position in the diaphragm, in one direction if the current increases, in the other if it decreases. In other words, every variation in the strength of the current causes a like motion in the diaphragm, and this motion corresponds to the changes in the current, not merely in their periods, but in the whole character of every change while it is passing from the maximum to the minimum strength. If, therefore, the strength of the current can be caused to exactly correspond to the character of the varying motions of an air particle when a particular sound is heard, the diaphragm of the re-
21 ceiver will be compelled to move with the same character of motion, will impart that motion to the air near it, and the sound in question will be there heard.

It will be observed that, comparing one instant with the next succeeding instant, the current may change by increasing or decreasing, and may vary in the amount of increase or decrease, may vary in the rapidity with which these changes in amount or in direction follow each other, and in the time it occupies in passing from one par-
22 ticular degree of strength through its whole series of changes, back to the condition of starting; in other words, the variations will be in the direction of change, in the amplitude of change, in the frequency of change. And the same is obviously true of the motions given to the diaphragm by the current. What is needed, therefore, is that the transmitting instrument, moved by the voice of

the speaker shall control, at every instant and without any interruption, the direction of change, the amplitude or violence of change, and the frequency of change in the current and thus make these conform to the varying changes of 23
motion in the air particles due to the voice of the speaker.

These three kinds of change — in direction, in amplitude, and in frequency — cover all the variations of motion and all the variations of current strength involved.

Mr. Bell's specification 174,465 describes both a method for transmitting telegraphically vocal and other sounds, and also several forms of apparatus by which that method can be practiced. The principle of his method or mode of operation, and the principle and mode of operation of his apparatus, is, that the electrical condition of the line wire 24
and parts connected with it, and hence the movement of the diaphragm of the receiver, shall be, not merely at intervals separated from each other, but continuously and without intermission, controlled by the movement of that part of the transmitter which is vibrated by and in accordance with the voice of the speaker. It is only by this continuous control that the character of the movement of the transmitter, in the sense in which I have used the word "character," is reproduced in the variations of the electric current and in the movements of the receiver. 25

This continuous control was not accomplished nor even attempted in any form of telephone known before Mr. Bell's invention.

No form of transmitter which involves the use of a circuit breaker can exercise this necessary constant control over the movement of the receiver. The circuit breaker will throw upon the line, at each time it makes contact, an electrical impulse due to the force of the battery, but these impulses will be merely intermittent. The effect of each on the line and on the receiver will die away with a rapidity 26
and with a character of decrease due to the physical constitution of the line and the receiver; the electrical and magnetic condition of the apparatus during these periods of intermission (and consequently the motion of the sound-

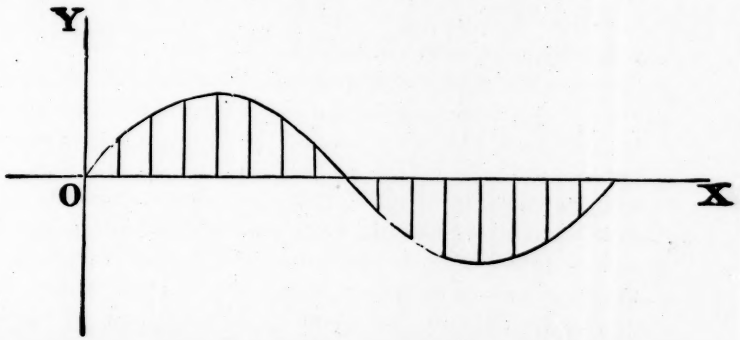
producing part of the receiver) will depend upon their physical constitution, and not upon the character of the movements performed by the transmitter during those periods. If such a circuit-breaking transmitter be moved by sound waves, as in the case of the Reis apparatus, the
27 frequency of its contacts will correspond to the pitch of the sound, a movement of the same frequency will take place in the receiver, and a sound of the same pitch will be reproduced. But all these characteristics which go to make up the quality of the sound, and which depend, as I have stated, not upon frequency of motion but upon character of motion, will fail of reproduction. The "quality" of the sound heard at the receiver will be that peculiar to the apparatus; consequently such an apparatus cannot transmit the words uttered by the speaker.

28 I have said that a circuit-breaking transmitter cannot *transmit* "quality," because the electrical and magnetic changes and consequent motions in the receiver during the intermissions of contact will be such as are due to the character of the apparatus, and not to the movement given to the transmitting diaphragm during these intervals by the voice of the speaker. Such an instrument would fail to be a speaking telephone for another reason. In all forms of apparatus which I know of, the sudden changes caused by totally breaking and then suddenly closing the circuit are
29 so much more violent than those due to merely weakening and strengthening the current, that the noise produced upon such an interruption renders it impossible for the listener to perceive those variations which constitute "quality," and make the sound intelligible as an articulate word. Indeed, this difference in the noise produced by making and breaking the circuit, instead of merely varying the current without breaking it, is so well understood that telephonic alarm signals are constructed to take advantage of it: a telephonic receiver, which, when actuated by artic-
30 ulate undulations, must be held close to the ear to be heard, will make a noise audible throughout a large hall, if an intermittent current from a circuit breaker be passed through it.

The method of transmitting vocal and other sounds by a constant and continuous control over the receiver through a current which is undulatory and continuous, and not intermittent or broken, and which itself is produced or controlled by and therefore conforms to the motion of the transmitter actuated by sound waves, is essential to the transmission of articulate speech, and I believe is novel 31
with Mr. Bell. This is the general opinion among scientific men who have studied the question. I will presently refer more in detail to the known state of the art on this subject before Mr. Bell's patent.

Before referring to the language in which Mr. Bell's specification describes his method, I will state the well-known meaning of some of the terms of the art which he employs.

It is common among physicists to represent graphically sound vibrations, or indeed any series of variations, by 32
curves. The following sketch represents the curve called a sinusoidal curve, such as corresponds to the sound waves produced by a simple sound, consisting of a single note without overtones. (Such a sound can be produced by a tuning-fork, mounted on a resonant case, and bowed in a manner suitable for this purpose.) O X is divided into



a number of equal spaces to represent equal periods of time. The length of these spaces is purely arbitrary.

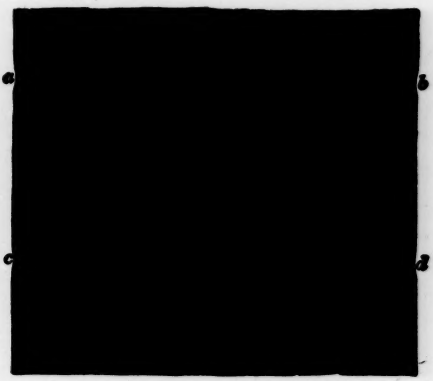
The distances from O to the beginning of any one of these
33 divisions are called *abscissas*. From each of these points on O X, representing successive intervals of time, lines are drawn parallel to O Y, and proportional in their relative lengths to the distances of the particle from the point of rest at the successive periods of time. In the case of the particle pursuing a simple vibration, these magnitudes will increase to a maximum which will be attained at the instant when it reaches the extremity of its path; they will then diminish, as it comes back to the starting point; and as it passes beyond it, moving in the
34 other direction, they will be indicated by distances measured off below the line O X. Joining then the extremities of the perpendicular lines, we obtain a broken line somewhat resembling a curve; and if we put the perpendicular lines close enough together, the broken line joining their extremities becomes a curve; this curve is determined by the length of two sets of lines or distances, — the *abscissas* measured on O X, and the *ordinates* measured paralled to O Y. In the case stated, the starting point is assumed to be in the middle of the path
35 (*e. g.*, the position of a pendulum when at rest), and the motion is measured in both directions from it; *i. e.*, the curve is on both sides of the line, and part of the ordinates have one direction, part the other. But the point from which the measurements are taken is purely arbitrary; and the line O X, which represents this point, might be placed lower down and tangent to the lowest part of the curve. In that case the curve would not change its character, but the ordinates would all be measured in one direction and on one side of O X. Algebraically expressed, they
36 would all be + quantities, instead of being alternately + and — quantities in the two branches of the curve; only the + quantities would be greater than shown in the diagram. In the case indicated by the diagram we should consider that an increase in the length of the ordinates, in passing from one to the next, signified motion in one direction, and a decrease signified motion in the other direc-

tion. In this method of representation one set of lines, measured along O X, corresponds to the period in which the movement is executed, or its frequency, and the other, measured along O Y, to the amplitude or extent and also to the direction of the motion; and these measurements express frequency, amplitude and direction. The same curve will represent the extent of rarefaction and of condensation of the air produced by the movement of the particles, and also, when correctly interpreted, the motion and the varying velocity of the particles. 37

It is from this habit of graphical expression that a vibration is commonly spoken of among physicists as having "form"; form of vibration is a phrase used to signify the "character" of a vibration, as I have explained it. 38

It must be remembered that this curve does not represent the path of the moving particle: that always moves to and fro in a straight line. This curve is merely a convenient form of expressing to the eye the character and variation of the motion.

The following diagram, taken from Mayer on "Sound," p. 153, represents the motion of a particle under the influence of sound waves:—



The curves at *a b* represent six sound waves of six simple sounds. When these are sounded together as fun- 39

damental and overtones, and with relative intensities corresponding to the amplitude of the curves, as drawn, so as to produce a sound having the quality due to this combination, the vibrational "form," as it is called, of the sound perceived by the ear is represented by the curve at *c d*. The set of vibrations which constitutes one complete vibration is shown twice between *c* and *d*. The entire "form" or character of this curve can be determined and controlled, as already stated, by determining or controlling for each
40 point the length of the abscissa and of the ordinate for that point, or in other words, determining or controlling the elements of time or frequency, amplitude or intensity, and direction; but it is obvious that it will require very many measurements of abscissas and ordinates to determine or control the "form" of each complete set of vibrations.

The curve representing one set of vibrations is about three inches long; and it is apparent, even to a casual observer, that by taking the ordinates as little as one eighth of an
41 inch apart, we should miss the little twists which most strikingly represent to the eye the "quality" or the effect of the overtones in this vibrational form, and which are equally important to the "quality" of the sound as perceived by the ear; and as in the articulate speech of a woman there are twenty-four thousand of these *complete* sets in a minute, it will be obvious that in order to reproduce this vibration the control must be exercised not merely twenty-four thousand times a minute, but really without any interruption or cessation whatever.

42 By a similar method, the variation in the strength of an electrical current can be graphically expressed or represented by a curve.

It is I presume, with reference to this well-known method of representation that Mr. Bell, in his said specification, states that the variations in the current caused by the movement of the transmitter can be represented graphically and without error by the same curve which represents the motion of the transmitter; and states, with

reference to the apparatus shown in Fig. 7, that the electrical undulations caused upon the line wire by the movement given to the transmitter by the sound uttered against it "are similar in form to the air vibrations caused by that sound; that is, they are represented graphically by similar curves." And it is to the same thing that the words "similar in form," used in the fifth claim, refer. 43

Theoretically, the forms of apparatus indicated by Mr. Bell's specification will give to this undulatory current, and to the diaphragm of the receiver, variations and motions similar to the form of the sound waves due to the voice of the speaker; and though I suppose no apparatus will conform perfectly to theoretical conditions, yet I know by experience that apparatus made exactly as there shown will produce such substantial similarity in these respects as to transmit articulate sounds and intelligible sentences. Its success in doing this depends upon the degree in which it approximates to the principles laid down by Mr. Bell in his specification. 44

I have described the method set forth in Mr. Bell's specification for transmitting vocal or other sounds telegraphically, by causing electrical undulations similar in form to the vibrations of the air accompanying the said vocal or other sounds. I have also described the receiving instrument, in which these electrical undulations cause aerial vibrations, and consequently sounds, at the receiving station, and I have stated that this receiver must be connected to the transmitter in an unbroken circuit over which the electrical undulations can pass. An essential part of the apparatus is a transmitter which shall cause electrical undulations similar in form to the sound waves produced by the voice of the speaker. 45 46

The instrument shown at A, Fig. 7, is a mechanical, but a most essential mechanical modification of A, Fig. 5; both depend upon the same electrical principle, but by reason of the entire change of structure shown in Fig. 7, it has become capable of transmitting vocal sounds of all kinds, including articulate speech. When this transmitter,

Fig. 7, is in operation, electric currents are generated in its coils by the motion of an inductive armature in front of the pole of a magnetized electro-magnet. When the ar-
47 mature approaches the magnet, this motion generates a current in one direction in the coils of the electro-magnet; when it recedes, its motion generates in them a current in the opposite direction.

The frequency of the changes in this current depends upon the frequency of the changes in the motion of this armature; and the extent of the changes, or the strength of the currents so created, depends upon and therefore corresponds to the violence of motion of the armature. There is a constant battery current flowing through the coils and
48 over the line, and when these magneto currents are in the same direction with it, they add to it and strengthen it; when in the opposite direction, they partially neutralize it and weaken it. When, as in the case of Fig. 7, the armature is attached to a diaphragm, which will be compelled by a sound uttered near it to move in substantial conformity to the aerial motion constituting that sound, the undulations of the current caused by the motion of the diaphragm of the transmitter, and similar in form to those motions, will also and consequently be similar in form to
49 the air vibrations which accompany or constitute the sound uttered, and which move the diaphragm of the instrument.

This form of transmitter is commonly called at the present time the magneto transmitter.

The patent also describes another method by which the motion of the diaphragm can be used to cause electric undulations similar in form to the motion of the diaphragm.

According to the well-known "Ohm's Law," the strength of an electric current is measured by the electro-motive force divided by the resistance. $S = \frac{E}{R}$. It was well known
50 before Mr. Bell's patent that the strength of a current could be varied, either by varying the electro-motive force, or by varying the resistance. Fig. 7 shows an apparatus which causes the desired undulations by varying the electro-motive force. The patent says that electrical

undulations may also be caused by alernately increasing and diminishing the resistance of the circuit; it also describes several forms of apparatus by which this can be accomplished.

I understand, therefore, that when the fifth claim refers to the method to transmitting vocal sounds by causing electrical undulations similar in form to the air vibrations, accompanying said sounds, it intends to include and does include undulations produced in a continuous voltaic circuit by all the methods specified in the patent as adapted to produce them, whether by vibrating an inductive armature in front of an electro-magnet, or otherwise varying the electro-motive force, or by vibrating an electrode forming part of the circuit, or by imparting vibrations to other parts of the apparatus included in the circuit, so as to vary the resistance of that circuit by such vibration.

The attention of physicists had been directed to attempts to transmit articulate speech before Mr. Bell's time, but entirely without success. The state of the art in this branch of the art of telephony is set forth in a description written by M. Bourseuil, and published in du Moncel's "Exposé des Application de l'Electricité," vol. ii. p. 225, published in 1854. This statement or indication was not accompanied by descriptions of any alleged apparatus as a whole.

Mr. Bourseuil's description is in substance as follows: "We know that sounds are made by vibrations, and are perceived by the ear by these same vibrations, which are reproduced by the intervening medium. . . . . Suppose that a man speaks near a movable plate flexible enough to lose none of the vibrations produced by the voice, and that this plate makes and breaks successively a battery circuit, you could have at a distance another plate capable of executing at the same time the same vibrations. It is true that the intensity of the sounds will be variable at the transmitting station where the plate is vibrated by the voice and constant at the receiving station where it is vibrated by electricity." And he proceeds to say that the existing state of science could not tell in advance what effect this would have on articulation. He sums up the state of knowledge on the subject by saying: "It is at all events impossible in the present condition of science, to prove the impossibility of transmitting sounds by electricity."

Subsequently, and in 1860-63 Philip Reis constructed and used in Germany an apparatus which embodied Bourseuil's ideas, though in a form which we now know is less efficient, so far as the receiver is concerned.

The Reis transmitter was described by Reis himself, and by various other persons, in printed publications before 1870, and was well known among scientific men. According to all of said descriptions it operated and was intended to operate by making and breaking an electric circuit at each vibration of the membrane of the transmitter. From this operation it necessarily followed that it was incapable of transmitting articulate speech, and its incapacity in this respect was well known and understood.

Later still Dr. Van der Weyde, in New York, in 1868, reconstructed the Reis apparatus with some improvements, which, however, did not change its mode of operation, nor the nature of the results produced. A description of it, published in the *Manufacturer and Builder* (of which Dr. Van der Weyde was the editor) for May, 1869, vol. i. p. 130, contains the following passage: —

"It is clear from the foregoing explanations that no quality of tone can be transmitted, much less can articulate words be sent, notwithstanding the enthusiastic prediction of some persons, who, when they first beheld this apparatus in operation, exclaimed that now we would talk directly through the wire. It is from its nature able to transmit only pitch and rhythm, consequently melody and nothing more. No harmony nor different degrees of strength or other qualities of tone can be transmitted; the receiving instrument, in fact, sings the melodies transmitted, as it were, with its own voice, regardless of the quality of the tone which produces the original tune at the other end of the wire."

The last word of science before Mr. Bell's patent was a description of this same instrument, written by Dr. Van der Weyde and published in the *Scientific American* of March 4, 1876, three days before the date of Mr. Bell's patent. This article, entitled "The Invention of the Telephone," redescribed the same apparatus, attributed to it the same mode of operation—*i. e.*, that it acted as a circuit-breaker—and claimed for it no higher power or function than was attributed to it by the same writer in 1869.

The absolute and inherent incapacity of the old instruments, or, indeed, of any circuit-breaker, to transmit articulate speech was thus perceived and publicly recognized; but what method or what character of instruments would accomplish this was not known and had not been suggested.

What was needed, therefore, for the transmission of articulate speech at the date of Mr. Bell's patent was not an improved apparatus constructed to operate according to the only method then known for the electrical transmission of sounds, but the invention of a new and fundamentally different method, and the construction of apparatus which should operate according to this method. It was necessary, not merely to introduce a new feature, but to totally discard that which was distinctive of the old method, and introduce in place of it another feature not only different from but inconsi-tent with the old method. It was not until after the introduction of Mr. Bell's new method, and only by the use of this new method, that articulate speech was, or, so far as my knowledge extends, ever has been, transmitted at all. The scientific world has generally recognized the "important point" or principle which distinguishes Mr. Bell's method from all preceding attempts, and which enabled it to accomplish what those previous methods of transmitting sounds were, both in theory and in practice, incapable of accomplishing. The introduction of this method has been the introduction of a new art. Since the date of Mr. Bell's patent many forms of speaking telephone have been made and patented; but, so far as my knowledge extends, they all embody the method, principle and mode of operation described by Mr. Bell in his said patent 174,465. So far as I am aware, these various modifications have been introduced in order to increase the practical efficiency of the method so described by Mr. Bell, and every change has been simply an endeavor to effect an improvement in the practical application of the new art set forth in said specification. The new method, which he described in said specification and referred to in the fifth claim thereof, underlies them all and includes them all.

The improvements in transmitters since Mr. Bell's patent 174,465 have been intended, and, so far as they have been successful, have

been adapted, to cause electrical undulations similar in form to the vibrations of the air, accompanying the vocal or other sounds which were uttered by the speaker at the transmitting end, and to do this by means of the vibrations given to the moving part of the transmitter by the voice of the speaker.

The improvements in the receivers have been intended to cause them to more perfectly and more fully move in conformity to these electrical undulations, and the receivers and transmitters have always been connected together in an unbroken circuit, in order that the movement given to one by the voice shall, at every instant and without intermission, control that movement in the receiver which produces the sound at the distant station.

Mr. Bell's second patent, No. 186,787, dated Jan. 30, 1877, refers to his previous patent 174,465, and sets forth certain improvements upon the apparatus shown in Fig. 7 thereof, which improvements render the apparatus better adapted to put in practice the method referred to in the fifth claim of the first patent.

One improvement shown in this patent consists in the acoustic arrangements of the box and frame. In Fig. 7 of the first patent the diaphragm is supported on a case which leaves its back side (next the magnet) exposed to the disturbing influence of all extraneous noises; and this case, in the transmitting instrument, offers a large cavity to talk into, and in the receiving instrument, a large cavity to receive the sound and conduct it to the ear. Figs. 1, 2 and 3 of patent 186,787 show a box which encloses and protects the back side of the diaphragm, while in front of it, in the place to be occupied by the sound waves which actuate it, or are produced by it, the cavity is diminished to a thin enclosure which communicates with the mouth of the speaker or the ear of the listener by a small hole in the centre. This modification of the front cavity was, so far as my knowledge extends, entirely novel with Mr. Bell. It possesses marked advantages in apparently intensifying the effect and preventing the formation of false tones. The advantages of it are so great and so well recognized, that this form of cavity in front and this protection for the back of the diaphragm are in universal use, the chief change being that the improvement has been pushed

still further by making the back cavity generally smaller and the front cavity still thinner.

The patent shows and states that a speaking tube "may" be inserted in the hole in front of the plate; but this tube is merely a matter of convenience if the telephone is too heavy to hold in the hand. In hand telephones it is generally replaced by the well-known form of flaring aperture long used in the acoustic instruments, known as Seebeck's ear, and described in works on acoustics. This sounding box is referred to in the sixth claim of said patent.

I have examined the description of a voltaic transmitter found in the affidavit of Edward Davis in this case. When this instrument is connected up in circuit with a receiver, such as the exhibit already described, or with any of the ordinary forms of speaking-telephone receivers, I am of opinion that it will transmit articulate speech. When transmitting articulate speech this apparatus will operate according to the method described in Mr. Bell's patent 174,465, and referred to in the fifth claim thereof; and it is capable of transmitting articulate speech because it will normally and habitually conform to the method and mode of operation therein described.

This transmitter is provided with a thin metallic diaphragm, and, when spoken to, this diaphragm takes up vibrations from the sound waves and conforms to them substantially in the character as well as in the frequency of its movements. These movements operate to cause, upon the line wire and in the receiver at the receiving station, electrical undulations similar in form to the sound waves accompanying or constituting the words spoken at the transmitting station. The instrument causes these undulations by means of the motion of an electrode, which is attached to the diaphragm, and whose motion serves to vary the resistance of the circuit external to the battery. This method is one of the methods for causing electrical undulations described in Mr. Bell's said patent. This particular form of instrument is not the same in all respects as that specifically described in said patent. I do not understand, however, that the patentee intends to confine himself to any specific form of instrument, but quite to the contrary; for, speaking of the various means for causing electrical undulations, he says, "The external resistance may also be varied. *For instance*, let," etc. And then he goes on to describe

been adapted, to cause electrical undulations similar in form to the vibrations of the air, accompanying the vocal or other sounds which were uttered by the speaker at the transmitting end, and to do this by means of the vibrations given to the moving part of the transmitter by the voice of the speaker.

The improvements in the receivers have been intended to cause them to more perfectly and more fully move in conformity to these electrical undulations, and the receivers and transmitters have always been connected together in an unbroken circuit, in order that the movement given to one by the voice shall, at every instant and without intermission, control that movement in the receiver which produces the sound at the distant station.

Mr. Bell's second patent, No. 186,787, dated Jan. 30, 1877, refers to his previous patent 174,465, and sets forth certain improvements upon the apparatus shown in Fig. 7 thereof, which improvements render the apparatus better adapted to put in practice the method referred to in the fifth claim of the first patent.

One improvement shown in this patent consists in the acoustic arrangements of the box and frame. In Fig. 7 of the first patent the diaphragm is supported on a case which leaves its back side (next the magnet) exposed to the disturbing influence of all extraneous noises; and this case, in the transmitting instrument, offers a large cavity to talk into, and in the receiving instrument, a large cavity to receive the sound and conduct it to the ear. Figs. 1, 2 and 3 of patent 186,787 show a box which encloses and protects the back side of the diaphragm, while in front of it, in the place to be occupied by the sound waves which actuate it, or are produced by it, the cavity is diminished to a thin enclosure which communicates with the mouth of the speaker or the ear of the listener by a small hole in the centre. This modification of the front cavity was, so far as my knowledge extends, entirely novel with Mr. Bell. It possesses marked advantages in apparently intensifying the effect and preventing the formation of false tones. The advantages of it are so great and so well recognized, that this form of cavity in front and this protection for the back of the diaphragm are in universal use, the chief change being that the improvement has been pushed

still further by making the back cavity generally smaller and the front cavity still thinner.

The patent shows and states that a speaking tube "may" be inserted in the hole in front of the plate; but this tube is merely a matter of convenience if the telephone is too heavy to hold in the hand. In hand telephones it is generally replaced by the well-known form of flaring aperture long used in the acoustic instruments, known as Seebeck's ear, and described in works on acoustics. This sounding box is referred to in the sixth claim of said patent.

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one particular instrument, in which the motion of an electrode attached to the diaphragm, as it vibrates to and from another electrode, which is fixed, will vary the resistance of the circuit. In the case of the defendants' said Eaton battery transmitter, the means by which the motion between the electrode fastened to the diaphragm, and moving with it, and the electrode fixed in the frame, varies the resistance, is not the same as that specifically described in the patent; but I do not consider that this changes the method or mode of operation of the apparatus as a whole, since in both cases vibrations of some part of the transmitter are produced by the voice, which in their turn produce corresponding electrical undulations in the line wire, by one of the two general means suggested by Mr. Bell for carrying out his method.

The mode of operation of this instrument and the functions of its operative parts are, that the vibrations imparted to the diaphragm by the voice do not break the circuit, but operate to vary its resistance, and thus, as Mr. Bell shows in his patent 174,465, by alternately increasing and diminishing the resistance of the circuit to cause electrical undulations, similar in form to the vibrations of the air accompanying the vocal sounds uttered at the transmitting station.

It was known long before the date of Mr. Bell's patent, that the resistance of a circuit is varied, without being broken, by variations in the intimacy of contact or amount of pressure between two electrodes in contact, from one to the other of which a current is passing. This fact was noted and recorded by Du Moncel in his book "Applications de l'Electricité," vol. ii. p. 246, edition of 1856, published at Paris in that year. In "Comptes Rendus" for July, 1874, a communication from the same writer described some experiments as to the resistance offered to the current in passing from one electrode to another, in the case where one was a good conductor and the other a poor conductor, and showed that a moderate increase of pressure at the contacts would materially increase the conductivity and thereby the current; and he gave his explanation for this phenomenon.

In Du Moncel, "Applications de l'Electricité," ed. 1856, vol i. p. 246, I find the following:—

"Une chose assez curieuse, et qui paraît être au premier abord en contradiction avec la théorie que l'on s'est faite de l'électricité, c'est que la plus ou moins grande pression exercée entre les pièces de contact des interrupteurs influe considérablement sur l'intensité du courant qui les traverse. Cela tient souvent à ce que les métaux de l'interrupteur ne sont pas toujours dans un état parfait de décapage au point de contact, mais peut être aussi à une cause physique encore mal appréciée. Ce qui est certain, c'est que, dans les interrupteurs où la pièce mobile de contact est sollicitée par une force extrêmement minime, le courant éprouve souvent des affaiblissements assez notables pour faire manquer la réaction électrique qu'on attend d'eux."

Which I translate as follows: —

"A somewhat curious fact, which at first sight appears to be in contradiction to the views ordinarily received as to the action of electricity, is that the greater or less pressure exercised between the contact pieces of interrupters has an important influence upon the strength of the current which traverses them. This often happens because the metal of the interrupter is not perfectly free from rust at the point of contact, but perhaps also because of a physical cause as yet but little appreciated. This is certain, that with interrupters in which a movable contact piece is acted upon by a very slight pressure, the current often sustained such an enfeeblement as to cause a failure in the electrical action which was expected."

The same writer describes, in "Comptes Rendus" for July 6, 1874, a series of experiments in which he measured the current in a circuit, part of which consisted of a platinum electrode and a piece of wood, more or less damp, kept in constant contact, but with varying pressure, and says, page 41, in an article entitled "Récherches sur les transmissions electriques a travers les corps ligneux," as follows: —

"Les expériences que j'avais à faire pour avoir une constatation exacte des effets produits, étaient assez delicates, car une foule de causes étrangères peuvent intervenir, et changer les résultats fournis. Ainsi le dégré de serrage des plaques metalliques de communication avec le bois, sur isolement plus ou moins parfait du sol et des murs de l'appartement, où l'on expérimente, la grandeur des surfaces mises en communication avec le circuit métallique, la masse du bois, l'état plus ou moins humide de l'air des expériences, le contact fortuit des doigts sur les fils de communication avec le galvananetre, et l'état d'isolemens de ces fils sont autant de causes qui peuvent modifier les résultats que l'on obtient.

. . . . . .

"6. Que le dégré de la pression de la plaque de platiné contre le bois a tellement influé sur l'intensité du courant ainsi transmis, qu' étant de 12 dégrés avec un serrage maximum elle est devenue à zéro quand la plaque était abandonné a son propre poids, et a 5 dégrés seulement avec un faible serrage."

This I translate as follows:—

"The experiments that I have had to make in order to have an exact proof of the effects produced were very delicate, because a number of foreign elements might enter and change the results. Thus *the amount of pressure upon the metallic plates in communication with the wood* is more or less perfect insulation from the earth or the walls of the room, the size of the surfaces put in communication with the metallic circuit, the mass of the wood, the greater or less humidity of the air, the accidental contact of the fingers with the wires leading to the galvanometer, and the condition of the insulation of these wires were causes which might modify the results that would be obtained.

. . . . . .

"6. That the amount of the pressure of the platinum plate against the wood has so much influence on the strength of the current thus transmitted, that from twelve degrees, with a maximum pressure, it became reduced to zero when the plate was pressed only by its own weight, and to five degrees only with a slight pressure."

In Du Moncel's "Traité de Telegraphie Electrique," Paris, 1864, Part IV, page 559, in speaking of apparatus designed to establish electrical contact, the author says, "L'expérience montre que plus la pression des contacts este grande, plus est énergique l'intensité du courant qui les traverse," that is, in English, "Experiment shows that the greater the pressure of the contact pieces, the stronger is the current passing through them."

This fact was also constantly acted upon in the practical use of electrical apparatus; care was always taken that contacts should be firm and with considerable pressure, for otherwise the full and desired strength of current was not obtained.

Speaking telephone battery transmitters which vary the resistance of the circuit by the movement of the diaphragm, without the use of the liquid, have been in common use upwards of two years and known somewhat longer. They contain generally a piece of carbon, or other substance of considerable resistance, which forms part of the circuit; the tendency of this piece to move away from the

diaphragm, when the latter is vibrated, is opposed by a firm and fixed support, which holds it in place, or by a tolerably stiff and sluggish spring, or by the inertia of a weight, either of which serves like an anvil, to resist a very quick and sharp impulse, such as comes from the vibrations of the diaphragm. Against the other side of this piece, which is very commonly called the "button," is an electrode, carried by or in contact with a diaphragm; as this diaphragm is vibrated by the voice, its varying motions bring to bear upon the button a pressure which varies in accordance to those motions, in character as well as in frequency, and the variations of resistance, due to this variation in pressure, cause electrical undulations in the circuit, which correspond in character, as well as in frequency, to the vibrations imparted to the transmitter by the voice of the speaker.

Mr. Emile Berliner's patent, No. 199,141, dated Jan. 15, 1878 (application filed Oct. 16, 1877), shows an apparatus of this sort which was described (so he states) in his application filed June 4, 1877. Mr. Thomas A. Edison's patent, No. 203,016, dated April 30, 1878 (application filed March 7, 1878), refers to an apparatus of this general character as shown in his application of July 20, 1877, and describes an instrument of this sort provided with a carbon button or disk, made of lampblack moulded into the proper shape.

I have examined the description of the Dolbear instrument, given in the affidavit of Edward Davis made in this case. The transmitter therein described is a variable resistance solid contact transmitter of this well-known class and, in my opinion, it is adapted to operate when spoken to by causing variations in the contact pressure without breaking contact. When it transmits speech it necessarily so operates.

The receiving instrument described in said affidavit of Edward Davis is not in all respects the same as that of Mr. Bell's said patent, but it is substantially the same in performing the work of the electrical transmission of speech, according to the method shown in Mr. Bell's patent 174,465 and claimed in claim five thereof. Both the instruments form parts of an apparatus, which, as a whole, transmits speech by means of certain peculiar variations of electrical currents. In this apparatus the office of the instrument at the receiving station is to convert these electrical undulations into corresponding

70
92

sound waves; and the particular means employed for that part of the operation do not affect the substantial indentity of the apparatus as a whole. There is, however, a great identity between these parts of the apparatus considered by themselves. In both the sound heard by the listener is produced by the vibrations of an elastic plate, and in both those vibrations are caused by the varying attractions to which it is subjected by the varying strength of the electrical undulations on the line wire. It is true that in the form shown in the two Bell patents the variation of currents causes magnetic variations in a piece of metal opposite the centre of a diaphragm, the attractive power of which piece is thereby caused to vary accordingly and thus cause variations in the attraction, while in the Dolbear instrument the variation of current causes electrical variations in a piece of metal opposite the centre of a diaphragm, the attractive power of which piece is caused to vary accordingly, and this causes variations in the attraction exercised on the diaphragm.

That the attractive power of one plate on another varied with the electrical condition of the first, was well known before the date of Mr. Bell's said first patent; it was also well known before the date of said patent, that by this means the electrical variations in the secondary circuit of an induction coil could be made to cause such vibratory motion in a plate as to thereby produce a sound whose pitch corresponded to the rate of the electrical variations. And this device for converting electrical variations into sound waves was well known as an equivalent and substitute for the motion given to a vibrating armature by means of the varying attraction of an electromagnet, through whose coils the same varying current should be passed.

I testified as expert for the complainants in the suit, in the U. S. Circuit Court for the District of Massachusetts, "American Bell Telephone Company *v.* Albert Spencer *et al.*" The transmitting instruments shown in said affidavit of Edward Davis are of the same character as, and operated in a similar manner to, the transmitter used by the defendant Spencer, and put in evidence in that case. The operative parts of both consist of a contact forming part of a battery circuit; one side of said contact in each is attached to an elastic diaphragm, which vibrates in accordance with the sound

waves when the diaphragm is spoken to, while the other electrode in contact therewith is so arranged, either by the manner of its support, or its mass and inertia, or both, as to offer considerable resistance to the movement of the diaphragm; by this arrangement the vibrations of the diaphragm when spoken to produce variations of pressure at the contact, which causes corresponding variations of resistance at this part of the circuit.

CHARLES R. CROSS.

STATE OF NEW HAMPSHIRE, }
CARROLL COUNTY, } ss.

Subscribed and sworn to before me,

[SEAL]

G. W. M. PITMAN,
Notary Public.

AFFIDAVIT OF THOMAS A. WATSON.

Thomas A. Watson, a witness of lawful age, having been duly sworn, doth depose as follows: —

My name is Thomas A. Watson, residence, Everett, Mass. As assistant to Mr. Bell, and afterwards as superintendent or in similar capacities, I have been connected with the manufacture and use of electric speaking telephones under Mr. Bell's patents, from the time when they first began to be manufactured or exhibited until I retired from business about May, 1881. All telephones that were made for Mr. Bell and his associates, and all that were made for the Bell Telephone Company and for the American Bell Telephone Company up to the time I left its employ, were manufactured under my supervision. 1

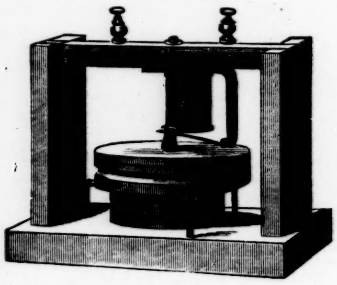
EARLY EXPERIMENTS.

In the winter of 1874–5 I was employed in making electrical instruments at the factory of Charles Williams, Jr., Boston, and had considerable knowledge of electricity and electrical apparatus, gained by three years' experience in that factory, and by the study of various works on electricity and telegraphy. At that time I began to make electrical apparatus for Mr. Bell, and assisted him in various experiments in the transmission of sound by electricity. 2

In January, 1875, Mr. Bell told me of plans he had devised for making a telegraph instrument which should utter spoken words. June 2, 1875, in consequence, as I understood it, of an experiment made that day, in which I had assisted him, and which he has referred to in his affidavit in this case, he directed me to make an electric speaking telephone according to instructions which he gave me. I made it that day or the next, and we tried it. When he shouted at this instrument at one end of a telegraph line, I heard and recognized the sound at another instrument at the other. He told me on that second day of June that he considered he had solved the problem of the transmission of speech. About a month afterwards I made 3

another similar instrument, which we experimented with. The annexed wood-cuts, marked respectively "First Bell Telephone of 1875," and "Second Bell Telephone of 1875," show these instruments almost exactly as they then were made.

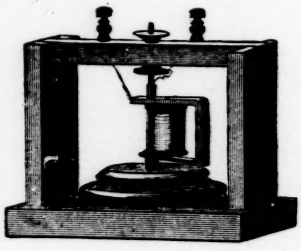
4 FIRST BELL TELEPHONE OF 1875.



DIMENSIONS.

Diameter of membrane	4	inches.
Diameter of spool	$1\frac{1}{4}$	"
Length of spool	$1\frac{1}{2}$	"
Length of armature	2	"
Width of armature	$\frac{1}{2}$	"
Depth of tube from mouth to membrane	3	"

SECOND BELL TELEPHONE OF 1875.



DIMENSIONS.

5	Diameter of membrane	$2\frac{3}{4}$	inches.
	Diameter of spool	$1\frac{1}{4}$	"
	Length of spool	$1\frac{1}{2}$	"
	Length of armature	2	"
	Width of armature	$\frac{1}{2}$	"

THE SPEAKING TELEPHONE PATENT.

In the fall of 1875 I knew that Mr. Bell was preparing the specifications for his patent 174,465, dated March 7, 1876.

This patent, dated March 7, 1876, was I verily believe, the first published description of any apparatus intended for, and capable of, or believed to be capable of transmitting vocal utterances telegraphically; it was the first published description and I believe the first description ever written of any mode or method capable of transmitting articulate speech or vocal utterances telegraphically. 6

INTRODUCTION OF THE SPEAKING TELEPHONE TO PUBLIC NOTICE AND USE, AND ITS RECEPTION.

May 10, 1876, a description by Professor Bell of his researches in telephony was read before the American Academy of Arts and Sciences, at Boston. This paper was published soon afterwards, and contained a description of his electrical speaking telephone, as shown in Fig. 7 of said patent, No 174,465; and described the transmission of speech by it. It also contained a description of an electrical speaking telephone made upon the plan of varying the resistance of an electrical circuit supplied with a constant electro-motive force from a battery; the particular form indicated was that known as the liquid transmitter, referred to in said specification, and was described as follows: — 7

"A platinum wire, attached to a stretched membrane, completed a voltaic circuit by dipping into water. Upon speaking to the membrane, articulate sounds proceeded from the telephone in the distant room. The sounds produced by the telephone became louder when dilute sulphuric acid or a saturated solution of salt was substituted for the water. Audible effects were also produced by the vibration of plumbago in mercury, in a solution of bichromate of potash, in salt and water, in dilute sulphuric acid and in pure water." 8

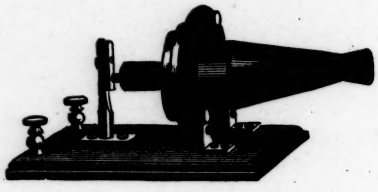
This was published in Vol. XII. of their proceedings.

EXHIBITION AND USE AT THE CENTENNIAL, JUNE, 1876.

9 Two sets of Professor Bell's speaking telephones were made by me for exhibition at the Centennial Exhibition in Philadelphia, and were exhibited there in June, 1876, before the judges of the group and many other persons. They consisted of a "magneto" transmitter and receiver, and of a liquid transmitter. I saw them there on exhibition.

They are referred to on pages 493, 544, 558, of the Dowd record. I produce drawings of the instruments as follows:—

BELL'S SINGLE POLE CENTENNIAL MEMBRANE TELEPHONE.



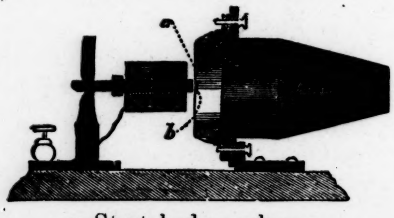
DIMENSIONS.

10

Length of cone	$5\frac{3}{4}$ inches.
Diameter of membrane	3 "
Length of spool	$1\frac{3}{4}$ "
Diameter of spool	$1\frac{3}{8}$ "

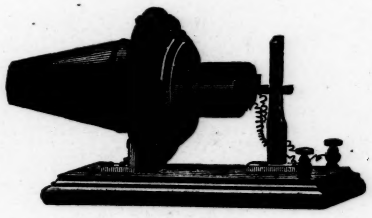
SINGLE POLE CENTENNIAL MEMBRANE TELEPHONE.

(Sectional view.)



a Stretched membrane.
b Steel spring armature.

BELL'S DOUBLE POLE CENTENNIAL MEMBRANE TELEPHONE.

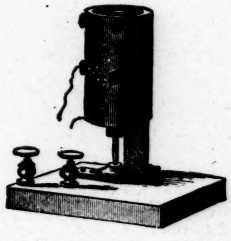


DIMENSIONS.

Length of cone	$4\frac{3}{4}$	inches.
Diameter of membrane	3	"
Length of spools	$1\frac{3}{4}$	"
Diameter of spools	$1\frac{3}{8}$	"

11

CENTENNIAL IRON BOX MAGNET RECEIVER.



DIMENSIONS.

Diameter of tube, ...	$1\frac{3}{4}$	inches.
Length of tube, ...	3	"

The diaphragm consisted of a soft iron disk laid loosely over the top. It has since been lost.

12 BELL'S CENTENNIAL LIQUID TRANSMITTER.

DIMENSIONS.

Diameter of membrane, ...	3 inches.
Diameter of cup, ...	$\frac{3}{4}$ "
Depth of cup, ...	$\frac{1}{2}$ "
Length of cone, ...	6 "

The depositions of Mr. A. G. Bell and of Mr. William Hubbard and of Mr. Elisha Gray, in the suit *Bell Telephone Company* v. *Dowd*, in the United States Circuit Court for the District of Massachusetts, describe one public exhibition of the
13 transmission of articulate speech by the magneto instruments, on June 25, 1876.

Two reports were made upon Mr. Bell's said exhibit. One, by Professor JOSEPH HENRY, in "General Report of Judges of Centennial Exhibition, Group, XXV.," pages 20 and 21, describes the apparatus and the transmission of speech by it, and is as follows: —

General Report of Judges of Centennial Exhibition Group XXV., pages 20 and 21.

THE ELECTRIC TELEPHONE AND MULTIPLE TELEGRAPH.

"The idea of transmitting sounds to a distance by means of electrical currents has been for several years before the world, and the idea of extension of this to telegraphy was evident, though no one had thought it could lead to practical results. But the idea of a multiple electrophonic telegraph transmitting simultaneously several different musical notes for the simultaneous transmission of different messages by one wire, is an invention of high scientific character promising admirable practical results. For the honor of this invention there are two claimants, Mr. Elisha Gray, of Chicago, Illinois, and Mr. Alexander G. Bell, of Salem, Massachusetts. These inventions are independent of one another and different in the method of producing the result. In the telegraph of Mr. Gray several series of waves or impulses are simultaneously transmitted through a single wire. These impulses are excited by interruptions in the current produced by tuning-forks of different pitches, and excite, at the farther extremity of the line, corresponding variations in tuning forks of the same pitch. Thus, if four or five tuning forks are vibrated at the same time at one end of the line, each will excite vibrations in its corresponding fork at the other end without affecting the other forks. The exhibitors of this telegraph inform the judges that they are now able to equip lines for actual business with a capacity for carrying, through one wire, eight messages simultaneously, and there is no reason why the number may not be increased to sixteen. This telegraph may be made self-recording, or may be worked forward by relays through greater lengths of line than the insulation allows in one circuit.

"The telephone of Mr. Bell aims at a still more remarkable result,—that of transmitting audible speech through long telegraphic lines. In the improved instrument the result is produced with striking effect, without the employment of an electrical current other than that produced by the mechanical ac-

tion of the impulse of the breath as it issues from the lungs in producing articulate sounds. To understand this wonderful result, suppose a plate of sheet-iron, about five inches square, suspended vertically before the mouth of the speaker so as to vibrate freely by the motion of the air due to the speech, and suppose also another iron plate, of the like dimensions, simi-
18 larly suspended before the ear of the hearer of the sound, and between these, but not in contact with them, is stretched the long telegraphic wire. Each end of this wire is attached to two coils of insulated wire surrounding a core of soft iron, the ends of which are placed near the middle of the plate, but not in contact with it. These four cores are kept in a magnetic condition by being attached at each end of the line to the two poles of a permanent magnet. Now it is evident that in this arrangement any disturbance of the magnetism of one of the permanent magnets, increasing or diminishing it, will induce
19 electrical currents, which, traversing the long wire, will produce a similar disturbance of the magnetism of the arrangement at the other end of the wire. Such a disturbance will be produced by the vibration of the plate of soft iron due to the words of the speaker, and the current thus produced, changing the magnetism of the soft iron cores, will by reaction produce corresponding vibrations in the iron plate suspended before the ear of the hearer. The vibrations of the second plate being similar to those of the first will reproduce the same sounds. Audible speech has, in this way, been transmitted to
20 a distance of three hundred miles, perfectly intelligible to those who have become accustomed to the peculiarities of certain of the sounds. All parts of a tune are transmitted with great distinctness and with magical effect.

"This telephone was exhibited in operation at the Centennial Exhibition, and was considered by the judges the greatest marvel hitherto achieved by the telegraph. The invention is yet in its infancy, and is susceptible of great improvements."

The othor report was made by Sir William Thomson, and is as follows. It is found in—

"Reports on Awards, Group XXV., Centennial Exhibition, pages 130 131. 21

"3. ALEXANDER GRAHAM BELL, SALEM, MASS. U. S.

"GRAHAM BELL'S ELECTRIC TELEPHONE AND MULTIPLE TELEGRAPH.

"*Report.*—The idea of an electric telephone, or apparatus for transmitting sounds to a distance by variations of electric current through a wire, has been for many years before the world, and has been realized in several ways, differing considerably in details as to the appliances at two points of the circuit for producing the variations of electric current and for deriving perceptible effects from them. An extension of this idea to some kind of electro-phonetic telegraphy was inevitable, even 22
though no one had thought it might or could lead to practically useful results. But the idea of a multiple electro-phonetic telegraph transmitting simultaneously several different musical notes and using intermissions of these (like intermissions of currents in so many separate wires) for the simultaneous and independent transmission of different messages by one wire, is a very fine invention, of high scientific character, promising splendidly useful practical results.

"This invention is claimed by Mr. Graham Bell, and he is entitled to full credit for it, even though, as I believe is the 23
case, it has been also independently invented by others, both in England and America.

"A very well worked-out realization of it is given in Mr. Bell's apparatus now exhibited. A great practical advantage of the electro-phonetic multiple telegraph over other methods of multiple telegraphy through one wire, is that no adjustment is required for varying conditions of the line to render the non-interference among the different messages perfect. Another even more important practical advantage is that it is indifferent between what points of the line and in which directions the 24
different messages are being sent. The different messages can in fact, be transmitted from any different points of the line, and each may be read at all other stations (whether stations from which others of the messages are being sent or not) with practically perfect non-interference. Another important advantage

is that earth currents and lightning discharges will never disturb the signaling.

"Mr. Graham Bell's apparatus includes an ingenious and
25 effective instrument for automatically making and breaking an electric contact every time one of his telegraphic musical notes commences and ceases to sound. Thus his multiple telegraph may be made self-recording (after the Morse or Bain method,) or may be worked forward by relay through greater lengths of line than imperfectness of the insulation allows to be worked in one circuit. Mr. Bell showed me in action two of these electro-phonetic relays, recording quite independently the transmission of independent messages by two musical notes in one wire.

26 "In addition to his electro-phonetic multiple telegraph, Mr. Graham Bell exhibits apparatus by which he has achieved a result of transcendent scientific interest—the transmission of spoken words by electric currents through a telegraph wire. To obtain this result, or even to make a first step toward it—the transmission of different qualities of sounds, such as the vowel sounds, Mr. Bell perceived that he must produce a variation of strength of current in the telegraph wire as nearly as may be in exact proportion to the velocity of a particle of air moved by the sound; and he invented a method of doing so, a piece
27 of iron attached to a membrane, and thus moved to and fro in the neighborhood of an electro-magnet, which has proved perfectly successful. The battery and wire of this electro-magnet are in circuit with the telegraph wire and the wire of another electro-magnet at the receiving station. This second electro-magnet has a solid bar of iron for core, which is connected at one end, by a thick disk of iron, to an iron tube surrounding the coil and bar. The free circular end of the tube constitutes one pole of the electro-magnet, and the adjacent free end of the bar-core, the other. A thin circular iron disk, held pressed
28 against the end of the tube by the electro-magnetic attraction, and free to vibrate through a very small space without touching the central pole, constitutes the sounder by which the electric effect is reconverted into sound. With my ear pressed

against this disk, I heard it speak distinctly several sentences, first of simple monosyllables, 'To be or not to be' (marvelously distinct); afterwards sentences from a newspaper, 'S. S. Cox has arrived' (I failed to hear the 'S. S. Cox,' but the 'has arrived,' I heard with perfect distinctness); then 'City of New York,' 'Senator Morton,' 'The Senate has passed a resolution to print one thousand extra copies,' 'The Americans of London 29
have made arrangements to celebrate the Fourth of July.' I need scarcely say I was astonished and delighted; so were others, including some other judges of our Group, who witnessed the experiments and verified with their own ears the electric transmission of speech. This, perhaps the greatest marvel hitherto achieved by the electric telegraph, has been obtained by appliances of quite a homespun and rudamentary character. With somewhat more advanced plans, and more powerful apparatus, we may confidently expect that Mr. Bell will give us the means of making voice and spoken words audi- 30
ble through the electric wire to an ear hundreds of miles distant."

The judges were: Joseph Henry, Sir William Thomson, J. E. Hilgard, James C. Watson, H. K. Oliver, F. A. Barnard, J. Schudmayer, E. Levasseur, P. F. Kupka, Ed. Favre-Perret, Chas. E. Emery.

This apparatus, and the transmission of speech by it, were noticed generally in the newspapers, and the invention attributed exclusively to Professor Bell. I instance the *Scientific American* of Sept. 9, 1876, the Boston *Transcript* of July 31
8, 1876, and the New York *Evening Post* of Sept. 5, 1876.

The Boston *Evening Transcript* of July 8, 1876, contains the following:

Notes at the Centennial.—" . . . Professor Bell has also a telegraphic and telephonic apparatus in his department for the transmission of many messages over a single wire, and of musical and articulate sounds by telegraph. The experiments which have been made in the presence of the Emperor of Brazil, Sir William Thomson, and others interested in the sub-

32 ject, have been highly interesting and satisfactory in their results."

The New York *Evening Post* of Sept. 5, 1876, contains the following:

"Yet the telegraphic and telephonic apparatus invented by A. Graham Bell should reconcile us to this loss. . . . Professor Bell has sent a valuable collection that well illustrates the mode by which many messages may be transmitted over a single wire, and also the ease with which musical and articulate sounds may be transmitted by telegraph. . . . Spoken
33 words may be thus transmitted."

The Boston *Daily Advertiser* of Sept. 25, 1876, says:—

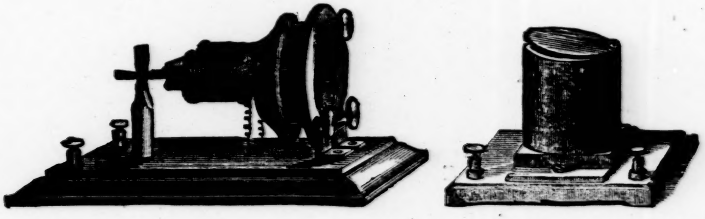
"The following passage, taken from the opening address of Professor Sir William Thomson, on assuming the chair of the section of physical science at the Glasgow meeting of the British Association, will be read with interest, as showing the impression made upon an English student of science, by our progress in discovery and in practical science: 'In the Canadian department, I heard, "To be or not to be," "There's the rub," through an electric telegraph wire; but scorning monosyllables
34 the electric articulation rose to higher flights, and gave me passages taken at random from the New York newspapers: "S. S. Cox has arrived" (I failed to make out the "S. S. Cox"), "The City of New York," "Senator Morton" "The Senate has resolved to print a thousand extra copies." "The Americans in London have resolved to celebrate the coming Fourth of July." All this my own ears heard, spoken to me with unmistakable distinctness by the thin circular disk armature of just such another little electro-magnet as this which I hold in
35 my hand. The words were shouted with a clear and loud voice by my colleague judge, Professor Watson, at the far end of the line, holding his mouth close to a stretched membrane, such as you see before you here, carrying a little piece of soft iron, which was thus made to perform, in the neighborhood of an electro-magnet in circuit with the line, motions proportional to the sonorific motion of the air.

"'This, the greatest by far of all the marvels of the electric

telegraph, is due to a young countryman of our own, Mr. Graham Bell, of Edinburgh and Montreal and Boston, now becoming a naturalized citizen of the United States. Who can but admire the hardihood of invention which devised such 36
very slight means to realize the mathematical conception that, if electricity is to convey all the delicacies of quality which distinguish articulate speech, the strength of its current must vary continuously, and as nearly as may be in simple proportion to the velocity of a particle of air engaged in constituting the sounds?'"

This address, or portions of it, containing the foregoing in full or in substance, was published in various newspapers.

A description of the electric speaking telephone, with woodcuts of a set of the apparatus given by Professor Bell to Sir 37
William Thomson, and the foregoing extracts from Sir William Thomson's address to the British Association, were published in *Engineering* for Dec. 22, 1876, and reprinted in the *Scientific American* supplement, Feb. 10, 1877. These publications attributed the invention to Professor Bell exclusively. The drawings in *Engineering* are as follows:



The receiver, as the drawing shows, has been bent and distorted out of shape before the wood cut was made in England.

During the fall of 1876, and the following winter and spring, Mr. Bell continued to experiment and operate publicly with 38
his speaking telephone, and these exhibitions were noticed very generally in the newspapers as matters of practical value. I assisted in most or all of these. The invention was invariably attributed to Professor Bell.

The Boston *Daily Advertiser* of Oct. 14, 1876, says:—

"At a meeting of the American Academy on Wednesday evening, Professor Bell exhibited his wonderful discovery by which sounds may be transmitted through wires by means of the electric current. By the invention of peculiar apparatus, conversation may be carried through hundreds of miles of
39 wires with the greatest ease."

The American Academy, at that meeting, passed a vote of thanks to Mr Bell, who, though not a member, had been specially invited to explain his invention to them.

The *Scientific American* of Sept. 9, 1876, contained the following:

"THE HUMAN VOICE TRANSMITTED BY TELEGRAPH.

"Several weeks ago we gave a sketch and description of the thread telegraph, consisting of two small tin or wooden cylinders, each having a membrane stretched over one end, the two
40 membranes connected by a stout thread. . . .

"Professor Graham Bell, by a device somewhat analogous, has succeeded in transmitting the tones of the human voice by telegraph. Instead of the thread, he connects the membranes of the two cylinders or drums with the armatures of the electro-magnets, one drum being placed at each end of the telegraph wire. In fact, he not long ago demonstrated the possibility of conveying vocal sounds by means of the ordinary telegraph wires and special appliances for transmitting and receiving the sounds. The apparatus used by Professor Bell is thus
41 described: Two single-pole electro-magnets, each having a resistance of ten ohms, were arranged in circuit with a battery of five carbon elements, the total resistance being about twenty-five ohms. A drumhead of goldbeater's skin, about two and three fourths inches in diameter, was placed in front of each electro-magnet, and a circular piece of clock spring was glued to the middle of the membrane of each drumhead. One of these telephones was placed in the experimental room, and the other in the basement of an adjoining house. Upon singing into the telephone the sounds of the voice were reproduced by

the instrument in the distant room; and if two persons sang 42
simultaneously, the two notes were audible at the other telephone.

"At the time of the lecture, an experiment was made to show the transmission of articulate speech, an assistant going into the adjoining building, where one of the telephones was placed. Several familiar questions were, it is said, understood after a few repetitions. The vowel sounds alone are those faithfully reproduced. Diphthongal sounds and rotund vowels are readily distinguished, but consonants are generally unrecognizable. Now and then, however, a sentence comes out with almost 43
startling distinctness, the consonants as well as the vowels being clearly audible. Professor Bell stated that telephonic effects can be produced with three varieties of currents,—the intermittent, the pulsatory and the undulatory. The first are characterized by the alternate presence and absence of electricity in the circuit, the pulsatory current by sudden changes in intensity, while undulatory currents are obtained by gradual changes analogous to the changes of density of air produced by vibrations of a pendulum.

"The most recent trial of Professor Bell's instrument was at 44
his residence, Brantford, Canada, Aug. 11. The Toronto *Globe* states that instruments were placed, one in the porch of the residence, and the other in an outhouse on the grounds, and communication between these made by ten miles of wire. Musical notes, the human voice, and songs spoken and sung before one instrument were plainly audible by placing the instrument to the ear at the other. By this invention, too, any number of messages can be conveyed over one wire in either direction, provided they have a different pitch; the tones of the voice can pass over the electric wire, enabling the hearer 45
at any distance to hear distinctly what is said, and to distinguish the voice of the speaker. On Aug. 10 the professor had communication made with his instrument on the common telegraph wire between Brantford and Mount Pleasant(five miles), and was spoken with, while in Mount Pleasant, by Professor D. C. Bell and Mr. Griffin, from the *Dominion* office, in Brant-

ford. On the evening of Aug. 12 the professor tried a new experiment, having had an instrument made so that three persons could sing different tunes, or different parts of the same
46 tune, into the instrument at the same time. The trial was perfectly successful, the different voices coming distinctly over the wire at the same time, so that they could be separately distinguished by the listener. The practical exemplification of the lately discovered system of telephony made by the professor afforded much pleasure and information to those present."

A long account of this Canadian exhibition is found in the Philadelphia *Record* of Aug. 17, 1876.

47 The Boston *Daily Advertiser* of Oct. 19, 1876, contained the following account of a trial of the telephone between Boston and Cambridge, by Mr. Bell and myself, which is substantially correct. As stated in the article it was the first conversation in the United States over what I call a telegraph line; that is, an outdoor line built for commercial purposes as usual with telegraph lines. Mr. Bell, I understood, had previously done the same thing in Canada, not, however, so fully recorded. Both the instruments used on this occasion were substantially the same as "Bell's single pole Centennial membrane telephone," but the mouthpieces were omitted:

48

TELEPHONY.

AUDIBLE SPEECH CONVEYED TWO MILES BY TELEGRAPH.

Professor A. Graham Bell's Discovery.—Successful and Interesting Experiments.—The Record of a conversation carried on Between Boston and Cambridgeport.

The following account of an experiment made on the evening of Oct. 9 [1876], by Alexander Graham Bell and Thomas A. Watson, is interesting, as being the record of the first conversation ever carried on by word of mouth over a telegraph

wire. Telephones were placed at either end of a telegraph line owned by the Walworth Manufacturing Company, extending from their office in Boston to their factory in Cambridgeport, a distance of about two miles. The company's battery, consisting of nine Daniell cells, was removed from the circuit, and another, of ten carbon elements, substituted. Articulate conversation then took place through the wire. The sounds, at first faint and indistinct, became suddenly quite loud and intelligible. Mr. Bell, in Boston, and Mr. Watson, in Cambridge, then took notes of what was said and heard, and the comparison of the two records is most interesting, as showing the accuracy of the electrical transmission:—

Boston Record.	*Cambridge Record.*
MR. BELL. What do you think was the matter with the instruments?	MR. BELL. What do you think is the matter with the instruments?
MR. WATSON. There was nothing the matter with them.	MR. WATSON. There is nothing the matter with them.
B. I think we were both speaking at the same time.	B. I think . . . at the same time.
W. Can you understand anything I say?	W. Can you understand anything I say?
B. Yes; I understand everything you say.	B. Yes; I understand everything you say.
W. The reason why you did not hear at first was because there was was a relay in the circuit.	W. The reason why it did not work at first was because there was a relay in the circuit.
B. You may be right, but I found the magnet of my telephone touching the membrane.	B. You may be right, but I find . . . that my . . . touches the membrane.
W. I cut this relay out, and then the sounds came perfectly.	W. I cut the relay out, and then the sounds came perfectly.
B. I hear every syllable. Try something in an ordinary conversational voice.	B. I hear every syllable. Try something in a conversational voice.
W. Shall I connect their battery in the circuit?	W. Shall I connect their battery in the circuit?
B. No; there is no necessity to connect their battery in the circuit, for the sounds come out quite loudly.	B. No; there is no necessity for putting their battery in the circuit, as the sounds come out quite loudly.
W. I am now talking in quite a low tone of voice.	W. I am now talking in quite a low tone of voice.
B. The sounds are quite as loud as before, and twice as distinct.	B. The sounds are quite as loud as before, and quite as distinct.

W. Cut out the battery and then talk.

B, All right; I will cut out the battery now if you will keep listening.

W. Cut out the battery and then talk.

B. All right; I will cut out the battery now if you will keep listening.

[Here an interruption occurred, and after a short time Mr. Bell said:]

54

B. I thought you were going to say something.

W. Is the battery cut out.

B. No; but I will do it now.

B. I thought you were going to say something.

W. Is the battery cut out?

B. No; but I will do it now.

[Battery having been cut out, Mr. Bell continued:]

B. Do you hear anything now?

[Battery replaced.]

B. Did you hear anything?

W. No; not a sound.

55

B. Say something to me when I cut out the battery again.

B. Did you hear anything?

W. No; not a sound.

B. Say something to me when I cut out the battery again.

[Battery cut out.]

W. . . . .

W. I could not hear a sound when the battery was cut out.

[Battery replaced.]

B. I fancy I heard a trace of your voice.

W. Shall I put on our battery, to see if it increases the effect?

56

B. I'll tell you what we'll do. We'll take off our battery, and put on theirs, as before.

B. I fancy I heard a trace of your voice.

W. Shall I put on their battery to see if it increases the effect?

B. I'll tell you what we'll do. We'll take off our battery altogether, and put on theirs as before.

[The company's batteries having been placed in circuit, faint and indistinct sounds were heard at the Boston end, and then came the intelligible sentence.]

W. Is our battery off?

B. Yes, our battery is off. What have you been doing? The sounds were quite soft at first, but

57

now they are quite loud.

B. Shall I put in our battery again?

W. (Indistinctly heard.) That was very indistinct. Put on our battery.

W. Is our battery off?

B. (Very indistinct—unintelligible.)

W. That was very indistinct. Put on our battery.

[Original battery replaced.]

B. We may congratulate ourselves upon a great success.

W. Both batteries are on now. (Another sentence heard indistinctly.)

B. Repeat the last sentence.

W. Both batteries are on now.

B. I understood that before, but thought you said something else.

W. Remove their battery, please.

B. All right; our battery is the only one on now.

W. I have put battery cells on here.

B. How many cells have you there?

W. S-i-x—six.

B. Please whisper something to me.

W. Sound of the whisper clearly audible, but the utterances unintelligible.

B. I could hear you whispering, but could not understand what you said.

W. Perhaps we have got the batteries opposed to one another. Had you not better reverse your battery and see what the matter is, or rather what the effect is?

B. I will try the effect of reversing my battery.

[Battery reversed.]

B. Is this any better?

W. That sentence was accompanied by that curious crackling sound.

B. Yes; I hear it too.

B. What time is it by your watch?

[Battery again reversed.]

W. What are you doing? I have not heard anything except . . . for quite a while.

B. I asked you what time it was by your watch. Perhaps you

B. We may congratulate our selves on our great success.

W. We deserve success. Both batteries are on now. 58

B. Repeat the last sentence.

W. Both batteries are on now.

B. I understood that before, but thought you said something else.

W. Reverse your battery, please.

B. All right; our battery is the only one on now.

W. I have six Daniell cells on here. 59

B. How many cells have you on there?

W. S-i-x—six.

B. Please whisper something to me.

W. Now I am whispering.

B. I could hear you whispering but could not understand what you said. 60

W. Perhaps we have got the batteries opposed to one another. Had you not better reverse yours and see what the effect is?

B. I will try the effect of reversing my battery.

61

B. Is this any better?

W. Much fainter, accompanied by that curious bubbling sound.

. . . . . .

. . . . . .

. . . . . .

W. What are you doing? I haven't heard anything except that bubling sound for quite a while. 62

B. I asked you . . . . . .

. . . . . .

hear me better now, because I have reversed the battery again.

W. My battery is now cut out.

B. Don't you think we better
63 go home now?

W. Yes; but why does your talking come out so much fainter now?

. . . . . .
. . . because I . . .
. . . . . .

W. My battery is now cut out.

B. Do you think we had better go home now?

W. Yes; but why does your talking come out so much fainter now?

[Mr. Bell here placed the magnet of the telephone nearer to the membrane.]

B. Because I had moved the magnet further away from the membrane.

W. That was very much more
64 distinct.

B. Will you try to understand a long sentence if I speak right on?

W. I will.

B. A few minutes ago I heard a fire engine pass by the door. I don't know where the fire is, but the number of the box is 196.

W. The time by my watch is
65 five minutes past ten. Had I not better go into Boston?

B. Yes; I think it is time to stop now.

W. Shall I go to Exeter Place?

B. Yes; but look in here on your way, in case I have not gone.

W. Let us talk conversationally, without noting.

B. Because I moved the magnet further away from the membrane.

W. That was very much more distinct.

B. Will you try to understand a longer sentence if I speak right on?

W. I will.

B. A few minutes ago I heard a fire engine go past the door. I don't know where the fire is, but the number of the box is 196.

W. The time by my watch is five minutes past ten. Had I not better go into Boston?

B. Yes; I think it is time to stop now.

W. Shall I go to Exeter Place?

B. Yes; but look in here on your way, in case I have not gone.

W. Let us talk conversationally, without noting.

Conversation was then carried on for about half an hour
66 with the utmost freedom, and the experiment closed.

The Boston *Evening Transcript* of Oct 19, 1876, says:

"*Telephony* . . . The registry of sounds by telegraph has now been carried to such a point that the delicate variations involved in the articulation of human speech are transmitted with such unerring accuracy and distinctness that one may talk with another through the telegraph as though face to face.

"The leading scientific men of the world gathered at Philadelphia last summer saw the fact accomplished on a small ex-

perimental scale. Sir W. Thomson was so impressed that in his opening address as president of the British Association he 67
described it at some length, and pronounced it the greatest by far of all the marvels of the electric telegraph. Ten days ago the test was repeated over an actual out-of-door telegraph between this city and Cambridge. The entire success of this experiment marks, for all that we can see, a revolution and advance in the world's progress worthy to rank with the practical completion of the first printing telegraph in New York City about forty years ago, and with the laying of the great ocean cables twenty years ago.

"The operation of this new and startling development of 68
telegraphic mechanism is thus described by Professor Thomson, in the address referred to:—

"'All this my own ear heard spoken to me with unmistakable distinctness by the thin, circular disk armature of just such another little electro-magnet as this which I hold in my hand. The words were shouted with a clear and loud voice by my colleague judge, Professor Watson, at the far end of the line, holding his mouth close to a stretched membrane such as you see before you here, carrying a little piece of soft iron, which was thus made to perform, in the neighborhood of an electro- 69
magnet in circuit with the line, motions proportional to the sonorific motions of the air.' . . .

"We give in another column the interesting account of the practical exemplification of the invention between Boston and Cambridge. The inventor, Mr. Graham Bell, is a young Edinburgh scientist, formerly of Montreal, but later of this city, and a naturalized citizen of the United States."

During the fall of 1876 and the following winter and spring, Mr. Bell operated publicly his electric speaking telephone. I assisted at most or all of these exhibitions. They were noticed 70
very generally in the newspapers as matters of practical value.

The invention was invariably attributed to Professor Bell. I mention

Boston *Post*, Oct. 20, 1876.

Boston *Daily Evening Traveller*, Oct. 19, 1876.

Boston *Sunday Herald*, Oct. 22, 1876.

Titusville *Herald*, Oct. 22, 1876.

Boston *Evening Transcript*, Oct. 19, 1876.

These describe the transmission of speech from Boston to
71 Cambridge.

The New York *Tribune* of Monday, Oct. 23, 1876, says:—

"The experiments which Professor A. Graham Bell has been recently making, relative to the transmission of speech by wire, have been quite successful. Two operators were stationed two miles apart, one in Boston and the other in Cambridge. The battery ordinarily used was replaced by one of ten carbon elements. At first the sounds were indistinct, but soon they grew clear and intelligible. The operators carried on a long conversation, and on subsequently comparing their
72 records ascertained that the tones had been transmitted with perfect accuracy."

An editorial in the New York *Tribune* of Nov. 9, 1876, contained the following:—

"The Centennial Exhibition has afforded the opportunity to bring into public view may inventions and improvements which otherwise would only have been known to the smaller circles that may find them of service. . . . The telephone is a new instrument of electrical science more likely than some of the rest to find immediate use. It operates by transmitting
73 the current through a tuning-fork. The fork will only vibrate a given number of times in a second. A message can be sent through it by the usual Morse code, there being no apparent interference between the tuning-fork vibrations and the message. But at the other end of the line the message can be taken off through a tuning fork in unison with the first. Consequently, if a tuning fork, of different pitch is interposed at each of several stations served by one wire, and the messages are sent through forks of corresponding pitch from the head office, the message to one station will not be repeated at the
74 others during transmission.

"Sir William Thomson, at the Glasgow meeting of the British Association for the Advancement of Science, gave foreign

notoriety to another of the Centennial exhibits that has attracted great attention from the judges of the group to which it belongs. It is a curious devise, that might fairly find place in the magic of Arabian tales. A membrane is stretched over the end of a short speaking trumpet. The membrane carries a small piece of metal which is, so to speak, the armature of a magnet. The magnet forms part of a telegraph circuit, through which a current is passing. To send a message, it is only 75
needful to talk loudly into the trumpet.

"The message is received by a similar trumpet with membrane and armature at the other end of the line; and that trumpet being placed to the ear repeats the sound like an echo. Don Pedro was with the scientific people who tested this instrument on one occasion; so accurately did it reproduce sounds that each member of the party was in turn recognized by peculiarities in voice or accent. The final test was the reading of a paragraph from the news columns of the *Tribune*. Of what use is such an invention? Well, there may be occasions of 76
state when it is necessary for officials who are far apart to talk with each other without the interference of an operator. Or some lover may wish to pop the question directly into the ear of a lady and hear for himself her reply, though miles away; it is not for us to guess how courtships will be carried on in the twentieth century. It is said that the human voice has been conveyed by this contrivance over a circuit of sixty miles. Music can be readily transmitted. Think of serenading by telegraph!"

Nov. 26, 1876, we carried on a long conversation on the 77
lines of the Eastern Railroad, using part of the time a circuit from Boston to Salem (15 miles), and part of the time a circuit from Boston to North Conway and back to Salem, and part of the circuit from Boston to Portland and back, about two hundred miles of actual telegraph wire.

This is noticed in—

Boston *Post*, Boston *Daily Globe*, Boston *Daily Advertiser*, and Boston *Herald*, of Nov. 27, 1876.

The Boston *Post* of Nov. 27, 1876, says: "The experiments

78 in electric telephony which Prof. A. Graham Bell has been conducting for several years past have resulted in the development of an apparatus by means of which the human voice, as ordinarily used in speaking, can be transmitted with certainty and ease to an indefinite distance—assuredly hundreds of miles. . . .

"The latest experiments with the telephone were made yesterday over the wires of the Eastern Railroad, that day being selected because the trials would not then be interrupted by the ordinary business of the line. Professor Bell, Presi-
79 dent Rockwell, of the Eastern Road, and wife, Miss Stearns, Mr. Morrison, and Mr. Hubbard, besides two telegraph operators, were the occupants of the Boston office. The instruments were arranged for about a twenty-mile test, consequently, Salem, about sixteen miles away, was the point at which the second telephone was fixed. Mr. Thomas A. Watson, assisted by the Salem operator, was in charge there. All those at the Boston end of the line held free and easy conversation with the Salem office, even a whisper or a loud breath being distinctly heard at one end when given at the other."

80 GENERAL USE IN PUBLIC.

Early in 1877, Professor Bell began to give public lectures upon and public exhibitions of the use of his electric speaking telephone.

Jan. 13, 1877, he gave a lecture on his electric speaking telephone, with an exhibition of it, before the Washington Philosophical Society, at Washington D. C. This was reported in the Washington *Evening Star* of Jan. 20, 1877.

The said report in the *Evening Star* begins as follows:—

"*Bell's Telephone.* At a meeting of the Washington Philo-
81 sophical Society on the evening of the 13th January, Mr. Bell, the inventor, gave to the members a description of the construction and operation of his most admirable and wonderful invention, *and exhibited it in operation.*"

The Boston *Daily Advertiser* of Jan. 22, 1877, contained the following:—

"The most important of the tests made recently by Professor A. Graham Bell, in the practical development of telephony, is dispensing with the use of the battery entirely, so that now all that is required to communicate between the most distant places is simply a line of wire and the telephones. 82

"Yesterday morning successful experiments were made between Boston and Salem, on the Eastern R. R. wire. At the Boston end were Professor Bell, Mr. Nutting, the operator, Mr. E. H. Foster, Mr. William Auld, and Mr. J. B. Parker; and at the Salem end Mr. T. A. Watson, who is associated with Mr. Bell, and the lady operator.

"Recently two Japanese gentlemen conversed in their own language through the telephones, and had no difficulty in understanding all that they said. An experiment has been made in overcoming an artificial resistance greater than the Atlantic 83 cable, and there is no doubt but that it will be possible to talk across the Atlantic."

The Boston *Evening Transcript*, of Feb. 1, 1877, contained a long description of an exhibition of a telephone, in which the following is found:—

"At noon, yesterday, a distinguished party of gentlemen were assembled at the office of the Boston Rubber Shoe Company, on Congress street, in order to witness a series of experiments performed on the telephone between the inventor, Professor A. Graham Bell, here, and his associate Mr. Thomas A. 84 Watson, at the residence of Mr. Converse, at Malden, about six miles distant.

"Professor Bell had been invited by some of our most prominent citizens to give a practical demonstration of the most recent developments of an invention which in accordance with its name, has already sounded far and wide the fame of the telephone. The experiments yesterday were as follows:

"Telephones having been connected with the private telegraphic line of the Boston Rubber Shoe Company, and the operators at either end having taken up their station, conversa- 85 tion was at once commenced. Stationed at the Boston end of the wire, Professor Bell requested Mr. Watson to speak in loud

tones, with a view of enabling the entire company at once to distinguish the sounds.

"This was so successful, that a smile of mingled pleasure and surprise played on the features of those present. That it, however, might not be supposed that loud speaking was essential to intelligibility, Mr. Bell explained that soft tones could be heard across the wires even more distinctly than loud utter-
86 ances, even a whisper being audible. In confirmation of this statement, Mr. Watson commenced speaking in turn to each member of the company, and after the efficiency of this method had been proved to the satisfaction of all, he took up a newspaper and informed the assemblage that gold had closed the previous evening at New York at $105\frac{5}{8}$.

"As there were quite a number of business men present, the effect that this practical demonstration of the value of the telephone produced can scarcely be exaggerated. Other passages from the daily journals were then given, and by this time the
87 desire for conversation having become general, Mr. Watson was plied with questions, such as, Is it thawing or freezing at Malden? Who is to be the next President? etc., etc. It was remarkable that Mr. Watson was able to distinguish between the voices at the Boston end, he calling at least one gentleman by name as soon as the latter commenced speaking.

"This went on for some time until a lady at the Malden end sent the company an invitation to lunch per telephone, and an appropriate response was made by the same medium.

"At length the company were requested to remain quiet
88 while a lady at the other end conveyed to them the sweet strains of music. The assemblage thereupon listened with rapt attention while a young lady commenced singing 'The Last Rose of Summer.' The effect was simply charming. Possessing, as the fair cantatrice does, a voice of exquisite sweetness, the sounds penetrated into the Boston end of the telephone with a distinctness equal to that attainable in the more distant parts of a large concert room, and a unanimous vote of thanks was sent by the handy little instrument which had procured for the assemblage so agreeable an hour.

"Among those present were electricians and gentlemen occupying prominent positions on our Western railroads, and one and all expressed the conviction that the telephone was destined to achieve the greatest possible results. Let us hope that the day is fast approaching when every man will be in a position to turn on the electricity in his house with the same facility with which he now turns on the water or the gas. 89

C. H. H."

He gave an exhibition in Salem, Mass., Feb. 12, 1877, and a report of it, published in the Boston *Globe* of Feb. 13, was *transmitted from Salem to Boston by his speaking telephone.* 90

The said *Globe* of Feb. 13, 1877, contained the following:—

"We have the pleasure of presenting to our readers this morning the first despatch ever sent to a newspaper by the newly invented telephone, Professor A. Graham Bell's system of transmitting sound by telegraph. The despatch was sent from Salem, where Professor Bell lectured last evening, our active representative in that city having secured the exclusive privilege of the instrument for that purpose. The message was received in this city by another representative of the *Globe*, who could readily recognize the voice at the other end. 91

. . . . . .

'SENT BY TELEPHONE.—THE FIRST NEWSPAPER DESPATCH SENT BY A HUMAN VOICE OVER THE WIRES.—TO THE DAILY GLOBE, FROM SALEM.—PROFESSOR GRAHAM BELL EXPLAINS HIS VALUABLE INVENTION.—AN ENTHUSIASTIC AUDIENCE.—HOW THE CAPACITY OF THE TELEPHONE WAS TESTED.

"*Special despatch by telephone to the Boston Globe.*

"SALEM, Feb. 12, 10.55 P. M.—Professor A. Graham Bell, the inventor of that wonderful instrument, the telephone, which has caused so much interest in the scientific world, and which is now becoming so popularly known, lectured on his invention at Lyceum Hall this evening. The lecture was one of a course of the Essex Institute, and about five hundred persons were present. 92

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"Mr. Watson was then asked to make a speech to the audience. He expressed himself as having more confidence
93 eighteen miles away than if he were present. His speech was as follows:—

"'*Ladies and Gentlemen*,—It gives me great pleasure to be able to address you this evening, although I am in Boston and you in Salem.' This could be heard thirty-five feet distant,—that is, all over the hall,—and brought down the house with applause. A system of questioning was then carried on, and Mr. Watson was asked if he heard the applause. The answer was, 'I was not listening; try again.' The applause was given, and its receipt at once acknowledged in Boston. Coughing and singing were then heard, and a variety of ques-
94 tions were then asked from the Salem end, and among them 'What news from the Electoral Commission?' followed by the distinct answer of 'I don't know of any.' But the news came fleeting along that the engineers of the Boston and Maine Railroad had struck. Gen. Coggswell asked if trains were running; the answer was clear and distinct that they were not at 5.30 o'clock. Professor Bell introduced the Rev. E. C. Bolles, who said, 'I shake hands with you cordially in imagination twenty miles away.' The Rev. E. S. Atwood asked, 'Does it rain?' 'It does not in Boston,' was Mr. Watson's
95 answer. Professor Gage, the electrician, then spoke through the telephone, endeavoring to have his voice recognized. This could not be done, as Mr. Watson was not familiar with the voice. Mr. Shaje Zsawa was recognized, Mr. Watson being perfectly familiar with his tones. One of the assistants in Boston then said that 'Hold the Fort' would be sung in Boston, and the tune which followed was readily recognized. Professor Bell closed his lecture by briefly stating the practical uses to which he was confident the telephone could be applied. Hearty applause was afforded the lecturer as he finished, and people flocked about the stage in large num-
96 bers to more closely examine the wonderful instrument that had placed them in audible communication with people nearly twenty miles away.

. . . . . .

"This special by telephone to the *Globe* has been transmitted in the presence of about twenty, who have thus been witnesses to a feat never before attempted; that is the sending of a newspaper despatch over the space of eighteen miles by the human voice; and all this wonder being accomplished in a time not much longer than would be consumed in an ordinary conversation between two people in the same room. 97

H. M. B.

"THE SCENE AT THE BOSTON END.

"The instrument which transmitted the wonderful voice message to the listening ears in this city was placed in a little room in Exeter Place, where were assembled Professor Watson, Benjamin Bridden, the electrician, Professor E. B. Warman, and Mr. A. B. Fletcher, representative of the *Globe*. The experiment was certainly a great success. The conversation with the friends eighteen miles away was carried on in ordinary tones of voice. The *Globe* representative in Boston very 98
easily recognized the voice of the transmitter of the despatch in Salem; and very distinctly heard the applause which was given in the Essex Institute Hall. It was a very noteworthy occasion, certainly; and the complete success attained led to the discussion of many plans for the further practical utilization of the telephone, which sends its first newspaper despatch to the *Globe* readers for their delectation and wonder, this morning."

The Boston *Daily Globe* of Feb. 15, 1877, contained the following:—

"THE TELEPHONE.—SOMETHING ABOUT THE CONSTRUCTION AND WORKING OF PROFESSOR BELL'S WONDERFUL INVENTION. 99

"As the telephone, the new invention of Professor A. Graham Bell, is but little understood, the following reprint of a description and explanation of the instrument may not be amiss:—

"'The telephone in its present form consists of a powerful, compound, permanent magnet, to the poles of which are at-

tached ordinary telegraph coils of insulated wire. In front of
100 the poles, surrounded by these coils of wire, is placed a diaphragm of iron. A mouthpiece to converge the sound upon this diaphragm substantially completes the arrangement. The motion of steel or iron in front of the poles of a magnet creates a current of electricity in coils surrounding the poles of the magnet, and the duration of this current of electricity coincides with the duration of the motion of the steel or iron moved or vibrated in the proximity of the magnet. When the human voice causes the diaphragm to vibrate, electrical undulations are induced in the coils environing the magnets
101 precisely analogous to the undulations of the air produced by that voice. These coils are connected with the line wire, which may be of any length, provided the insulation be good. The undulations which are induced in these coils travel through the line wire, and, passing through the coils of an instrument of precisely similar construction at the distant station, are again resolved into air undulations by the diaphragm of this instrument.'

"It was by this wonderfully simple instrument that the three quarter of a column report of Professor Bell's lecture
102 was transmitted from Salem to the GLOBE by the voice on Monday evening. All who saw the working of the instrument were astounded at the results obtained."

The following report of the Salem lecture appeared in the Salem *Observer* of Feb. 17, 1877:

"SATURDAY, Feb. 17, 1877.

"THE TELEPHONE.—The illustrated lecture upon telephony by Professor A. Graham Bell, was exceedingly interesting. The results exhibited were indeed amazing; nearly every experiment was successful. . . .

"On Monday evening Mr. Watson, who was in the Boston
103 office, 'wired' several tests to the audience of five hundred who were assembled in Lyceum Hall. He conversed with Professor Bell freely; the latter asking questions in an ordinary tone of voice, with distinct articulation, and the answers immediately returning and having a sort of muffled sound.

Mr. Watson addressed some words to the audience in Salem, which were distinctly heard, and the applause which followed was heard by him in Boston. He sang 'Auld Lang Syne' and other pieces, and played upon a reed organ, all the sounds of which were duly delivered at the Salem end of the wire. The person in Boston was also heard to cough and laugh. During the evening Rev. Dr. Bolles, Rev. Mr. Atwood, Professor Gage, General Cogswell, a gentleman from Japan, and a lady (Miss Loring), all spoke successfully through the telephone. A full report of the meeting was sent to the *Globe* by telephone from its correspondent, Mr. Batchelder. 104

"The apparatus by which this astonishing result is secured is wonderfully simple; only a telegraphic wire, a horseshoe magnet, two helices and a vibrating disk, at each end. The audience see only a mahogany box upon the table, of the appearance of an ordinary photographer's camera. The tube in the end is used in this case to speak into and to hear out of. Within the box is a horseshoe magnet. Opposite each arm of the magnet is a helix of the usual construction. 105

"One end of the wire among the helices is connected with the ground, and the other with Boston, or the place in operating connection. Set up against the helices, within a sixteenth of an inch, is a sheet of thin polished iron, upon which the voice of the operator impinges when speaking. The magnet induces an electrical current in the telegraphic wire. The vibrating disk imparts pulsations to this electrical current corresponding to the sounds, which are conveyed to Boston, and reproduce themselves upon the vibrating disk there with exactness of tone and articulation. The little four inches of iron utters the whole gamut of the human voice. This is indeed wonderful,—the greatest achievement of modern science. Another exhibition of the telephone is to be given." 106

The following is an extract from an article in the New York *Sun* of Feb. 20, 1877:—

"PROF. BELL'S TELEPHONE.—THE HUMAN VOICE CARRIED
107 A HUNDRED AND FORTY MILES.—MARVELOUS STORIES ABOUT THE LATEST ACHIEVEMENT OF SCIENCE.—MUSIC IN SALEM AND APPLAUSE IN BOSTON.—THE CONSTRUCTION AND CAPABILITIES OF THE INSTRUMENT DESCRIBED.

* * * * * * * *

"The honor of having received the first newspaper despatch ever sent by means of the telephone belongs to the Boston *Globe*. A report of a lecture by Professor Bell, in Salem, was transmitted verbally to it last Monday night. This lecture was about the telephone, and in the course of the evening a
108 series of remarkable experiments was made in the presence of the audience. Songs and brief speeches were sent from Boston, and the applause which greeted their reception in Salem was distinctly heard in Boston. Imagine sitting in a hall and hearing a man eighteen miles away, sing 'Hold the Fort.'

"'I haven't the slightest doubt,' Mr. Watson said to-day, 'that in a few months things will be so that a man can make a lecture here in Boston and be heard by an audience in any part of the country.'

"'Do you expect that the telephone will entirely supersede
109 the present system of telegraphing?' I asked.

"'Yes, we expect it will, eventually. A company is now forming for the purpose of manufacturing and introducing the instrument. In time it can't fail to replace the old dot and line alphabet system entirely. We expect, at first, it will be used mostly on private lines and for city business. It will probably take the place of the present district telegraph companies and the like, as it will be especially convenient for that class of business.'

* * * * * * * *

110 "The wonderful little instrument, of whose future value to civilization the inventor is so sanguine, consists of a powerful compound permanent magnet, to the poles of which are attached ordinary telegraph coils of insulated wire. In front of the the poles, surrounded by these coils of wire, is a diaphragm of iron A mouthpiece, whose function is to converge the sound upon

this diaphragm, substantially completes the arrangement. The operation of the instrument is thus described by Professor Bell.: The motion of steel or iron in front of the poles of a magnet creates a current of electricity in coils surrounding the poles of the magnet, and the duration of this current of 111
electricity coincides with the duration of the motion of the steel or iron moved or vibrated in the proximity of the magnet. When the human voice causes the diaphragm to vibrate, electrical undulations are induced in the coils around the magnets precisely similar to the undulations of the air produced by the voice. The coils are connected with the line wire, and the undulations induced in them travel through the wire, and passing through the coils of another instrument of similar construction at the other end of the line, are again resolved into air undulations by the diaphragm of this instrument. 112
The voltaic battery is entirely dispensed with. The line wire may be of any given length, provided the insulation be good. Professor Bell further says that soft tones can he heard across the wires even more distinctly than loud utterances, even a whisper being audible."

Feb. 23, 1877, a second lecture and public exhibition was given at Salem. *A long report of this was transmitted by telephone*, and published in the Boston *Daily Globe* of Feb. 24, 1877. That report contains the following:—

Special Despatch by Telephone to the BOSTON GLOBE. 113

"SALEM, Friday, Feb. 23, 10.20 P. M.—Lyceum Hall has been crowded this evening with an audience of five hundred, which had assembled to hear Professor A. Graham Bell's interesting lecture on his wonderful invention, the telephone and the results obtained by the evening's exhibition were certainly most astonishing. This was the second public exhibition of the new invention and its practical uses, and Salem has been fortunate indeed in having both given before her citizens. This second lecture and exhibition was given in response to an invitation to Professor Bell by a number of 114
scientific gentlemen and prominent citizens, and the audience

was one which only a rare and notable occasion can draw together in Salem. Among the more prominent people in the audience were the Hon. George B. Loring, Judge Endicott, of the Supreme Court, Professor D. B. Hagar, of the State Normal School, Dr. J. R. Nichols, of Haverhill, editor of the Boston *Journal of Chemistry*, Judge Osgood, Mayor Oliver, Aldermen Daton and Stone, Professor John Robinson, Ex-Mayor Williams, Dr. Henry Wheatland, President of the Essex
115 Institute, the Rev. Messrs. Arey, Dean, and Atwood, John W. Perkins, master of the Salem High School, General William Cogswell, J. S. Packard, Esq., and many other prominent citizens. The experiments were similar to those given at the former lecture, and were eminently successful, receiving hearty applause. Professor Thomas A. Watson, Professor Bell's assistant, transmitted several messages from the Boston end of the telephonic wire.

. . . . . .

"The company at the Boston end of the telephonic wire between Boston and Salem was quite as numerous as Professor
116 Bell's laboratory could well accommodate. It is a little room at the end of Exeter Place, up three flights of stairs, with the various instruments of the telephonic apparatus to be seen on every hand. On one of the tables were the models on which Professor Bell worked out the telephone as it now exists; and they form an interesting study. Books, letters and papers, all pertaining in more or less degree to the science of electricity, arranged about the room, which is plainly and tastefully furnished. Occupying the post of duty near the working instrument was Professor Thomas A. Watson, Mr. B. F. Bridden
117 having charge of the working of the electric apparatus, with two young lads as assistants. The company present included Mr. D. P. Richards, who has been one of Professor Bell's coworkers, the Hon. Charles Levi Woodbury, John C. Hoadley, of Lawrence, Dr. Henry I. Bowditch, Dr. C. J. Blake, Mr. W. A. Hovey, and Mr. C. E. Hurd, of the *Transcript*, three gentlemen from one of Dr. Tourjée's Tabernacle choirs, a cornet player, and an artist who was illustrating the scene for the

Scientific American, besides reporters from the various city papers.

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"THE GLOBE despatch then came, followed by another press message, giving merely the news furnished by THE GLOBE about the telephone a week ago. Then 'Yankee Doodle' and 'Auld Lang Syne' were sung by Professor Bell, and distinctly heard in every tone by all in the room; and at 10.30 the conference came to an end."

The Providence *Press* of Feb. 24, 1877, has a long account of the Salem lecture, which contained the following:—

THE PROVIDENCE PRESS.

FEB. 24, 1877. 119

"We willingly surrender space to-day to the somewhat enthusiastic report by a member of our editorial staff who was invited to witness the experiments with the telephone last night at Salem. The importance of the invention promises to be such as to make all obtainable knowledge of it valuable, and we do remember to have yet seen any so detailed and intelligible description of its workings as our representative furnishes.

. . . . . .

"HOW THE THING IS DONE, 120

is, of course, the practical reader's demand. It is done by a magnificent effort of genius, making itself felt with common tools. It is simplicity embodied and almost made personal. There is not even a battery to send an electric current along the line, for the affair is sufficient unto itself within its six by twelve inch dimensions, asking nothing of existing telegraphy but the wires it has strung. The principle is the familiar one that a plate of iron presented to a coil of insulated wire on the end of a magnet causes an electric current to traverse the magnet, provided the circuit is complete. Professor Bell, 121 therefore, takes a horseshoe magnet, places on each of its ends a nearly flat spiral wire, and just in front of the points of the

spirals, an infinitesimal distance away, sets up his plate of iron. To complete this circuit, he connects one arm of the magnet with the earth, by means of the gas pipes, and the other communicating wire runs out from the other arm to wherever the other operator may be stationed, with a similar earth connection on the magnet at his end." . . .

122 On the occasion of this Salem lecture I was at the Boston end of the telephone line, and the account given in the papers which I have quoted from is substantially correct, so far as came under my knowledge. I made the instruments used, and they are correctly described.

The lecture at Salem was followed by a series of lectures in Boston, Providence, Lowell, Manchester and New York, and these were extensively noticed in newspapers in different parts of the country: *e. g.*, the New York *Sun*, Feb. 11, 1877, had nearly a column about the lecture at Salem; the Boston *Journal of Chemistry*, March 1, 1877, had a long account; also
123 the New York *Times; Daily Graphic*, of March 6, 1877, with illustrations; *Scientific American*, March 31, 1877, with illustrations; *Frank Leslie's*, March 31, 1877, with illustrations; *The Athenæum*, London, England, March 3, 1877. At all of them electric speaking telephones with metallic diaphragms were used; at all of them the electric speaking telephones were publicly exhibited, their construction and operation explained, and they were publicly used in the transmission of articulate speech. At these exhibitions an admission fee was charged and paid by the audience. The following
124 accounts of them are substantially correct, so far as they came within my knowledge. The instruments used were made by me, or under my supervision.

The following is the opening paragraph of the article in Boston *Journal of Chemistry*, of March 1, 1877, above referred to:—

BOSTON JOURNAL OF CHEMISTRY.

Boston March 1, 1877.

"THE TELEPHONE.

"The telephone is the invention of Professor A. Graham

Bell, of this city, and has resulted from a course of inductive reasoning, growing out of a careful study of the philosophy of 125
sound, as related to wave motions in air, and in metals when induced by electrical excitation. The instrument is exceeding simple and inexpensive, and easily understood. It consists in attaching to the terminals of the ordinary telegraph wires, between any two points, powerful compound magnets, with coils of wire connected. In front of the pole, surrounded by these coils of wire, is placed a diaphragm of iron. A mouthpiece to converge the sound upon the diaphragm, substantially completes the arrangement. When the human voice causes the diaphragm to vibrate, closing and breaking the circuit 126
with each vibration, electrical undulations are induced in the coils, precisely analogous to the undulations of the air produced by that voice. These coils are connected with the line wire, which may be of any length, provided the insulation be good. The undulations induced in these coils travel through the line wire, and, passing through the coils of an instrument of precisely similar construction at the distant station, are again resolved into air undulations by the diaphragm of this instrument."

The Providence *Journal*, of March 15, 1877, had a long article on the telephone, from which the following is an ex- 127
tract:—

"THE LAST GREAT WONDER.

. . . . . .

"In the telephone no galvanic battery is used. A permanent steel magnet is surrounded with a coil of insulated wire, and confronted with a disk of sheet iron. When the iron disk vibrates, under the influence of sound, it disturbs the magnetism of the steel magnet before it; and, by a familiar law, every change of magnetism in a magnet excites an electric current in a surrounding coil. The coil is connected with the tele- 128
graph wire, and that with the coil around the magnet at the further end of the line, the ground being used for the return circuit. The distant magnet thrills with the electric current so excited, and vibrates the disk in front of it, which, in turn, impresses sound waves on the air."

The Boston *Daily Globe*, of April 6, 1877, had a report of the Providence lecture, from which the following is taken:—

"PROFESSOR BELL EXHIBITS ITS WONDERFUL WORKINGS TO A PROVIDENCE AUDIENCE.—A SUCCESS DESPITE UNFAVORABLE CONDITIONS.—
129 A SPECIAL TO THE 'GLOBE' BY TELEPHONE.

"Professor A. Graham Bell, the inventor of the telephone, lectured in Providence last evening; and in his little room at the top of No. 5 Exeter Place, Mr. Thomas A. Watson, the electrician, with several members of the press and a number of gentlemen interested in science, were assembled, for the purpose of holding communication with the professor, and demonstrating anew the practical workings of the instrument.

. . . . . .

"The *Globe* reporter remained with Mr. Watson until a late
130 hour; and when the audience in Providence had been dismissed, and all the visitors had left the room in this city, he was repaid for his waiting by receiving the following message from a brother reporter of the *Globe*, who went to Providence especially to send a telephonic despatch:—

"'THE EXHIBITION IN PROVIDENCE.

"'*Special to the* GLOBE *by Telephone.*

"'PROVIDENCE, R. I., April 5.

"'The bad weather prevented the exhibition from being as effective as usual; still the audience which crowded Music
131 Hall, and represented the best society of the city, had conclusive proof of the value of the invention. The transmission of musical sounds from the reed organ in Boston, giving "Music in Air," and other familiar tunes, were admirably perfect, and was heard distinctly all over the hall. The exhibition of singing was fairly successful; and Mr. Reeves' cornet solo, "Yankee Doodle," played at the request of one of the audience, was recognized very easily. The experiment of brass-band playing was not very successful. A conversation carried on between the Rev. Dr. Behrends here, and Mr. Watson at Bos-
132 ton, on the Rhode Island election, caused much merriment.

Governor Lippett introduced Professor Bell, who spoke till after ten o'clock, and remained in the hall an hour after, exhibiting the telephone to a curious crowd. An effort will be made to have the lecture repeated, when, it is hoped, circumstances will be more favorable for the working of Professor Bell's invention.'

"[NOTE.—On account of damage to the wires it was impossible to send as full a despatch as was intended; but, fortunately, the accident did not happen until after the lecture had been delivered, and Providence people had been satisfied 133
of the success of the invention.]"

The following is an extract from a report of the lecture which appeared in the Providence *Daily Journal*, of April 6, 1877:

"PROFESSOR BELL'S LECTURE ON THE TELEPHONE.

"Music Hall was filled last evening, notwithstanding the storm, by one of our best audiences, to witness the first public exhibition of the speaking telephone in this city

. . . . . .

"Professor Bell stated that in vocal utterance it is best to 134
remove the battery, and use nothing between the telephonic intruments in Boston and Providence. The Boston office was then telegraphed to cut out the battery. While waiting for this to be done, Professor Bell explained in a few words the structure of his instrument and its history.

. . . . . .

"Mr. Watson next sung 'Hold the Fort,' which was switched on to the different telephones. Mr. Watson then repeated a sentence which was switched on to the telephones and generally heard. Rev. Mr. Behrends then interviewed Mr. Watson, 135
asking him if it was stormy in Boston, also 'What time is it?' and 'Have you heard the news from Rhode Island?' Mr. Watson had not. Mr. Behrends informed him that we had an election yesterday, and 'Did you hear who was elected?' Yes, Mr. Watson had read it. 'What is the news in Boston?'

Answer, 'I have not heard any.' 'Good night Mr. Watson,' closed the conference.

* * * * * * * *

"The mysterious little box at Professor Bell's lecture con-
136 tains an apparatus almost elementary in its simplicity, which answers the double purpose of transmitting and receiving sounds. It may be divided into two parts, the artificial ear and the magneto-electric transmitter. The artificial ear may be likened to a grocer's sugar funnel, of tin or other metal (having a tube of about two inches diameter,) the large flaring end of which has been sealed with a circular disk of thin sheet iron. This disk is the tympanum of the artificial ear. The two-inch tube is the part which projects from the box into which you talk, and at which you listen for a reply. In-
137 side of the box there is a fixed, U-shaped steel magnet, whose poles very nearly approach the sheet-iron disk, keeping it in a state of tension by virtue of magnetic attraction. Around the arms of the U magnet, near its poles, are bobbins of fine insulated copper wire, which communicate together, and one of the free ends of which connects with the telegraph wire outside, and the other with the ground, for the return current. For certain reasons it is thought better, in practice, to attach small, soft iron cylinders, on which the bobbins are placed, to the poles of the fixed magnet; and the ends of these cylinders
138 then take the place of the poles of the magnet, in close proximity to the iron disk or tympanum. This is virtually the whole apparatus. When a word is whispered into the two-inch auditory tube it causes the iron tympanum to vibrate. This disturbs the magnetism of the fixed magnet, and of its soft iron cylindrical poles. This disturbance, in its turn, induces electrical currents in the coils of fine wire and in the telegraph wire outside. At the distant station these processes are then taken up in reverse order. The induced currents, passing from the telegraph wire through the coils of the re-
139 ceiving instrument, disturb the magnetism of the fixed magnet there, and that sets the disk in front of it in vibration, which communicates in turn the same sound undulations to the air

which originated this curious series of transformations. In other words, the persons listening at the distant disk hear the same words, accents, tones, which were confided to the disk at the near station. It will be observed that the sound waves are converted first into mechanical vibrations of the disk, then into magnetic vibrations, then into electric currents, then back into magnetic vibrations, then into vibrations of the distant 140 disk, and lastly into sound vibrations again,—and that these transmutations of the original sound waves between the two disks require four jumps through air spaces."

I was at the Boston end of the line, and had entire charge of the experiments by which the lecture was illustrated, and I conversed with a large number of people in Providence, and succeeded in making my voice audible to a large part of the audience at once. I received by telephone the newspaper dispatch for the Boston *Globe*.

The *Sun*, *Tribune*, *Herald*, *World* and *Times*, of New York, of May 12, 1877, had long accounts of an exhibition of the 141 speaking telephone by Professor Bell, in the presence of General Eckert, President of the Atlantic and Pacific Telegraph Company, President Gibbs, of the Dominion Telegraph Company, President Barnard and Professors Newberry and Rood, of Columbia College, and many others, at the St. Denis Hotel. The following is the article from the New York *Tribune*:—

"An exhibition of the speaking telephone was given last night at the St. Denis Hotel, in this city. An invitation to exhibit the instrument here had been tendered to Professor A. Graham Bell by Professor F. A. P. Barnard, Dr. Howard 142 Crosby, Professor Henry Morton, and two or three dozen other gentlemen eminent in the learned profession or connected with telegraph. Before beginning his proposed course of lectures, Professor Bell invited a few of his scientific friends to be present at an informal exhibition, to show the power of the instruments. About fifty gentlemen were gathered in one of the parlors of the St. Denis Hotel last evening. Among those present were President Barnard, Professor O. N. Rood, and Professor J. S. Newberry, of Columbia College; the Rev. Dr.

143 Armitage; General Eckert, President of the Atlantic and Pacific, and the Hon. T. N. Gibbs, President of the Domestic Telegraph Company; Professor Peet, of the Dea fand Dumb Asylum; Eastman Johnson, General Gaylord, S. A. Bunce, R. H. McCurdy, F. O. Evans, and other well-known citizens. There was some delay about the proceedings, which was afterwards explained.

"Professor Barnard introduced Professor Bell to the audience, having become acquainted with the instrument and the inventor at Philadelphia. Professor Barnard stated that
144 of all the instruments of precision and research, etc., which the group of Centennial judges, of which he was chairman, was called upon to examine, there was none that occasioned greater interest or that they regarded as of higher novelty and importance than the speaking telephone of Professor A. Graham Bell. In introducing Professor Bell to the audience, Professor Barnard said that he did so with the conviction that the name of the inventor of the telephone would be handed down to posterity, with a permanent claim on the gratitude and remembrance of mankind. Professor Bell expressed him-
145 self as surprised at the size and importance of the gathering. He had at first expected only a small number of his friends, and had arranged to exhibit his telephone merely by placing one of the instruments in one room, and another in another room, in the hotel, connecting them by wires. But at a late hour he had determined upon a more complete exhibition of the character of the instrument, and therefore sent his assistant, Mr. Gower, to Brooklyn, and hoped before long to hear that Mr. Gower had arrived somewhere in that city, and to hear it from Mr. Gower through the telephone. While Pro-
146 fessor Bell was speaking, a sound was heard from the instrument; he placed his ear against it, and after listening for a moment, said to the audience: 'It is all right. Mr. Gower has been in search of a cornet player, and thinks he will have one to play a tune for us.' Professor Bell then carried on a brief conversation with Mr. Gower, finally desiring the latter to be in readiness after a short interval, in which Professor Bell proposed to explain some features of the instrument to his audience.

"Professor Bell mentioned many of the facts with which our readers are already familiar, as to the construction and character of the instrument. When a magnet approaches a 147
bar of iron, it generates a current or a change of electrical condition in the iron; when it is drawn back it generates the converse electricity: *i. e.*, in one case positive, in the other negative. What Professor Bell had done was to substitute a sheet or plate of iron for the bar, to make that vibrate instead of the magnet, and to keep the magnet stationary. The vibration was communicated to the plate in front of the poles of the magnet by the waves of sound striking on the plate. These differences of positive and negative electricity, transmitted through the wire, caused a magnet at the other end of the wire
to attract or repel a precisely similar iron plate; and the vibra- 148
tions of that communicated to the air, were sounds precisely corresponding to those presented at the first plate. He has tested it on two hundred and fifty-eight miles of wire between New York and Boston. He commenced by understanding it; now he does not understand it.

"The vibration was supposed to be like that of a membrane, such as is that of the drum of the ear. But we all know that such vibration can be readily dampened by fastening upon the membrane something to stiffen it.

"There was no such result with the telephone when a wood- 149
en ring was screwed to the plate; or when the plate itself was made of extraordinary thickness, the vibration is molecular. The curious sounds heard in the telephone were described; some of them had beenascertained to proceed from earth currents. The instrument was more sensitive than a galvanometer to certain imperfections in the wire, or imperfect connections.

"The cornet player at last arrived. He was borrowed for a brief period from the orchestra of a neighboring theatre. He played two tunes, the latter one being very distinctly
heard. When the note happened to strike the fundamental 150
note of the telephone box it sounded abnormally loud. Otherwise it was fairly rendered. The voice in Professor Bell's in-

strument sounds very much as though it had come through a very long speaking tube. Some practice is necessary to catch the words uttered, the vibrations giving a sort of confusing rattle. Nevertheless, the success of the transmission is unquestionable.

"After Professor Bell had finished speaking, the different
151 members of the audience listened at the instrument, and some of them conversed with Mr. Gower, who was at the telegraph office, No. 340 Fulton Street, Brooklyn. Much laughter was occasioned by Professor Bell getting the word Fulton wrong, after asking Mr. Gower where he was; Professor Bell understood him to say 'Beacon Street,' perhaps having Boston in his mind. The proprietors of the St. Denis Hotel invited the visitors to a repast after the exhibition."

The first New York lecture was given May 17, 1877, at Chickering Hall, and long reports of it were in the New York
152 *Herald*, *Tribune*, *World* and *Times* of the next day. These reports stated that President Barnard and Professor Rood, of Columbia College, President Morton and Professor Mayer, of the Stevens Institute, Mr. Cyrus W. Field, Mr. William Orton, and General Eckert, and Messrs. Preece and Wheeler (of the English Postal Telegraph) were present, and that Mr. Field spoke through the telephone to the operator at Brunswick.

The lecture in New York, at Chickering Hall, was preceded by the following request, which was published in the daily papers:

153 NEW YORK, April 7, 1877.

"PROFESSOR A. GRAHAM BELL, *Boston University:*

"*Dear Sir*,—The interest excited during the Centennial Exhibition by your experiments with your telephone, holding communication in audible speech with persons many miles away, and the published accounts of your improvements in the wonderful instrument, prompt us to request that you will deliver in our city, on some evening convenient to yourself, a lecture on sound and electricity, with an exhibition of your

speaking telephone, showing what can be done by it, and making known its scientific and commercial value. 154

"Very truly, etc.,

"F. A. P. BARNARD [*President Columbia College*].
HOWARD CROSBY [*Chancellor of New York University*].
HENRY MORTON [*Stevens Scientific School*].
E. L. YOUMANS [*Ed. Popular Science Monthly*].
CYRUS W. FIELD [*Atlantic Cable*].
THOS. T. ECKERT [*Pres. Atlantic and Pacific Tel. Co.*]
A. M. MAYER [*Stevens Scientific School*].
WILLIAM ORTON [*Pres. Western Union Tel. Co*].
J. S. NEWBERRY [*School of Mines, Columbia College*]. 155
C. T. CHANDLER [*Prof. Chemistry, College Phys. and Surgeons*].
H. D. NOYES, [*Prof. Aural Surgery, Bellevue College*].
JNO. W. DRAPER *Prof. Chemistry, N. Y. University*].

At Boston three lectures were given in the Music Hall in May, 1877, at the first of which Professor Bell was introduced by Governor Gaston, and at each of them articulate speech was publicly transmitted. The exhibitions at Boston and Providence were reported in the principal newspapers: *e. g.*, Providence *Journal* of April 6, 1877, the Boston papers of April 6, and of May 5, 8, 9, of 1877. 156

The Boston lectures were preceded by the following, which was published in the daily papers:—

BOSTON, April 20, 1877.

"Professor ALEXANDER GRAHAM BELL:

"*Sir*,—The undersigned, having followed with great interest the accounts of your discoveries and inventions in connection with the electric telephone, which have from time to time appeared in the newspapers, and confident that the general public of the city in which your researches have been made will 157 be glad to witness a practical exhibition of your telephone under your direction, respectfully request you to gratify this de-

sire of your fellow-citizens at such time and place as may be most convenient to you.

"BENJAMIN PIERCE [*Prof. Mathematics, Harvard College*].
JOSEPH LOVERING [*Prof. Physics, Harvard College*].
E. N. HORSFORD [*formerly Rumford Prof., Lawrence S. School*].
HENRY W. LONGFELLOW [*Cambridge*].
158 GEO. B. EMERSON [*Boston*].
O. W. HOLMES [*Boston*].
CHARLES W. ELIOT [*Pres. University at Cambridge*].
ALEXANDER H. RICE [*Governor of Massachusetts*].
NEHEMIAH GIBSON [*Boston*].
FREDERICK O. PRINCE [*afterwards Mayor of Boston*].
WILLIAM F. WARREN [*Cambridge*].
JOHN D. RUNKLE [*Mass. Inst. Technology and Naut. Al.*]
C. F. ADAMS [*Quincy*].
WOLCOTT GIBBS [*Prof. Lawrence Scientific School.*
159 EDWARD C. PICKERING [*Prof. Physics Mass. Inst. Tech., now Director of the Observatory at Cambridge.*]"

I will refer to the following publications, though I was not present on the occasions described:—

Dr. Henry Morton gave a lecture on the telephone, and an abstract of it is in the New York *Herald* of June 14, 1877.

The *Journal of the Telegraph*, March 1, April 1, April 16 and May 16, 1877, describe and refer to Mr. Bell's electric speaking telephone, and to Mr. Bell as the inventor thereof.

The *Scientific American* of Oct. 6, 1877, has a long article
160 entitled "The New Bell Telephone." It is illustrated by large wood cuts of the hand telephone now in common use and of the manner of using the same. Said article described the structure of the apparatus, and its mode of operation. It concludes with the following paragraph:—

"The telephone has advanced considerably beyond the status of a 'beautiful scientific toy,' which many hastily pronounced it, and is now in constant use on numerous private lines in New York, Boston, and Providence. Professor Bell recently exhibited it before the British Association at Plymouth, England, where it attracted great attention. It is at present man-

ufactured by the Telephone Company of New York, Mr. 161
Charles A. Cheever, Manager, 32 Tribune Building in this city."

About Aug. 1, 1877, Mr. Bell went to England to introduce the electric speaking telephone abroad. At that time there were about 1,000 in use under license from him; there were not any in use, so far as I know, or have ever heard, without license from him. All the publications on the subject had referred to him as the first and original inventor of the electric speaking telephone; and at that time I had not heard that any one claimed to have invented it before him, or to have transmitted articulate speech by electricity before he did. Up 162
to this day I have never heard of any claim publicly made by any one before August, 1877. I have not since then heard even of any alleged secret inventor of it before him, with the exception of the persons I will presently name.

Mr. Edward S. Renwick, called as an expert witness for the defence in the "Telephone Suits," testified (page 231.)

"*Cross-Int.* 45. When did you first have any knowledge of the speaking telephone . . . .?

"*Ans.* . . . . The first knowledge I had was through 163
printed descriptions. . . . . It must have been in the year 1877. . . . .

"*Cross-Int.* 46. Do you remember whether the first printed account of them which you read, spoke of them as a new invention, and did it attribute the invention of them to anybody?

"*Ans.* . . . . My impression is that they spoke of the telephone as a new invention, and attributed it to Professor Bell."

Mr. Frank L. Pope, electrician, called as an expert witness for the defence in said suits, said that in the summer of 1877, he saw used in Boston a pair of telephones which were identi- 164
fied as Bell Telephones, made by Mr. Bell's licensees. They were in fact made under my supervision. Referring to that trial of them, he testified (page 340.)

"*Cross-Int.* 41. Had you ever before that heard articulate speech transmitted over a telegraph wire by means of electricity?

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fied as Bell Telephones, made by Mr. Bell's licensees. They were in fact made under my supervision. Referring to that trial of them, he testified (page 340.)

"*Cross-Int.* 41. Had you ever before that heard articulate speech transmitted over a telegraph wire by means of electricity?

"*Ans.* I had not.

"*Cross-Int.* 44. When did you first learn by actual observation and study the interior construction of a speaking tele-
165 phone?

"*Ans.* About the first of August, 1877.

"*Cross-Int.* 46. [The telephone you then examined] was made or purported to be made under the Bell patents, did it not?

"*Ans.* It was so marked and stamped."

Mr. Elisha Gray, examined as a witness for the defence in the same suit, testified (page 138) that he listened at the receiver of Mr. Bell's telephone when it was exhibited to the judges at the Centennial, June 25, 1876, and heard words, and
166 that it was the first time he had ever listened at a speaking telephone apparatus for the purpose of hearing what it would do."

The *Popular Seientific Review*, an English publication, for 1877, p. 429, has an article of four pages on electric speaking telephones, in which it refers to Gray as an inventor of the harmonic instrument, and Edison as the inventor of an important improvement, but attributes the main invention to Bell. It says:—

"THE TELEPHONE.—During the recent session of the British Association at Plymouth, the lion's share of attention was
167 "unquestionably given to the telephone. Wherever the in-
"strument was to be exhibited, whether in the physical or in
"the mathematical sections, or at Mr. Preece's popular even-
"ing lecture, there were always crowded audiences, eager to
"learn something about so novel an apparatus. At the *soirées*
"too, the telephone stood above everything else as the centre
"of attraction, and knots of people were crowded round the
"instrument, anxious to converse with friends in distant apart-
"ments. The interest in this subject culminated on the arri-
"val of Professor Graham Bell, the inventor of the talking
168 "telegraph."

The Mr. Preece referred to is, I presume, Mr. W H. Preece, of the English Postal Telegraph, vice-president of the Society of Telegraph Engineers. A paper by him on the telephone

was published in the *Philosophical Magazine* for April, 1878. It begins as follows:

"The introduction of the speaking telephone, by Alexander, "Graham Bell, has supplied physicists with an instrument of "research, as well as with an instrument of practical utility."

I annex the opening paragraph of a long article, under the caption of "The Telephone," which appeared in the West- 169
minister *Review* for January, 1878, (208):—

"Of all modern inventions connected with the transmission of telegraphic signals, the telephone, devised by Mr. Alexander Graham Bell, has excited the most widespread interest and wonder. Wherever Mr. Bell has appeared before the public to give an account of his invention and researches which have led up to it, crowds have assembled to hear him. Nor is this astonishing; for the telephone professes not only to convey intelligible signals to great distances without the use of a battery, but to transmit in *fac simile* the tones of the human voice, so that a voice shall be as certainly recognized 170
when heard over a distance of a few hundreds of miles as if its owner were speaking in a room by our side. And the telephone does not fall short of its profession. Scientific men have had their wonder and curiosity aroused even more than the unscientific public, since a scientific man appreciates the enormous difficulties to be overcome before such an instrument can be realized. Had any hardy speculator a few years ago proposed a telephone which should act on the principle and be constructed in the form of Mr. Bell's instrument, he would 171
probably have been considered a lunatic."

Mr. Bell's patent 174,465 of March 7, 1876, was the first patent ever granted which claimed or showed an apparatus intended for the transmission of vocal sounds. During the first year after that patent none were granted which purported to relate to the subject, except patent 186,787, to Mr. Bell. During the second year only three were granted, of which one was to me, and one to Mr. Berliner, for improvements relating to telephones. Between then and March 7, 1882, more than two hundred and seventy-five have been granted for improve- 172

ments in electric speaking telephones, and nearly as many in other appliances intended for use with telephones.

In the autumn of 1877, and after Mr. Bell had gone abroad, we heard that the Western Union Telegraph Company and its associates were satisfied with the great commercial value of the telephone to the public and to their own telegraphic interests, and that they were preparing to make and use telephones so soon as they could make the arrangements they thought needful for the purpose.

173 With this view, as I understood, they formed, about Dec. 1, 1877, a corporation called the "American Speaking Telephone Company." Their advertisements stated that they owned the inventions of Edison, Gray, Dolbear and others, and the list of directors included the president and principal officers of the Western Union and Gold and Stock Telegraph Companies. It was not, however, until about the summer of 1878 that they began to put out telephones to any serious extent.

Mr. FRANK L. POPE, the electrical expert of the Western Union Telegraph Company, was called by the defendant in
174 the suit of Bell Telephone Company *v.* Dowd, and testified as follows in his third and fourth answers, pages 319, 320:—

"Some time during the summer [of 1877], being in Boston on business, I saw and talked through a speaking telephone for the first time, and within a short time thereafter, which was in the month ot August, 1877, I was directed by Mr. Orton, then president of the Western Union Company, to make a thorough examination of the whole subject, as far as practicable. I accordingly made such an investigation, and from that time until the present have endeavored to inform
175 myself as completely as possible of everything in relation to the subject of speaking telephones.

"The directions which were given me by President Orton were, to the best of my recollection, entirely verbal. I had before mentioned to him the fact of my having seen and talked through a telephone in Boston (I suppose it to have been a Bell telephone); and it was some days after I had mentioned this to him that he sent for me, and said to me in substance,—

I do not pretend to give his exact words,—'I have been looking into this matter of the telephone somewhat, and regard it as a matter likely to be of considerable future importance. If 176
this proves to be the case, it is very necessary that we should have the right to use it; therefore I wish you to make a careful and thorough investigation of the whole subject and ascertain what are the fundamental principles of the invention, and what inventions or patents it will be desirable or necessary for us to acquire the control of, in order to be able to use the invention in connection with our business.' I accordingly set about this investigation, and was engaged in it for two or three months, all the time I could spare from my other duties." 177

Suits were brought under Mr. Bell's said two patents against those who used the telephones of said infringing associated corporations, and one of them, Bell Telephone Company *et al.* *v.* Peter A. Dowd, in the United States Circuit Court at Boston, was vigorously pushed for trial. That suit was defended by the Western Union Telegraph Company and its associates, and the counsel for the defendant were Mr. George Gifford, Mr. Causten Browne and Mr. W. D. Baldwin; Mr. Edward S. Renwick and Mr. Frank L. Pope testified as experts for the defence. 178

The defendant set up that Mr. Bell was not the first inventor, and to anticipate one or more of his claims he named three persons as prior inventors, viz., Elisha Gray, Thomas A. Edison and Amos E. Dolbear. It has appeared that the American Speaking Telephone Company owned all the telephonic inventions of these three persons. Evidence in chief for the complainants was taken and completed; evidence for the defense was taken and completed; evidence for the complainants in reply was taken and completed; the whole forming about 1,200 printed pages. After this it was agreed that all the tele- 179
phones used by the defendant and put out by the Western Union and Gold and Stock Telegraph Companies and their associates should be sold to the Bell Telephone Company at less than cost, should be put under license from the Bell

company under the Bell patents, for which the established and usual royalties should be paid, and that the corporations defending the suit should retire form the business of manufacturing telephones and should not use any telephones except those to be obtained from the Bell Telephone Company,
180 for all of which they should pay the usual and established royalties to the Bell Telephone Company. It was further agreed that the Bell company should have an exclusive license for electric speaking telephones and their appliances, under all patents applicable thereto which the said associated corporations owned or controlled.

In consideration of this, those other companies were to receive one fifth part of the royalties collected by the Bell Telephone Company on electric speaking telephones.

It was understood by me, and I heard from others at the
181 time, that the result of the evidence had satisfied the counsel for the defence that Mr. Bell was the first and original inventor of the electric speaking telephone, and that the settlement was based upon that belief. The Bell Telephone Company was satisfied that the evidence sustained fully Mr. Bell's claims, and was led to make the arrangement mentioned for the purpose of avoiding protracted and expensive litigation, and because of the immediate pecuniary advantages which it offered, and because the Bell company desired an unquestionable license under certain patents and inventions controlled by their op-
182 ponents. One of these patents, on which suit had been brought against the Bell company and those using instruments fur nished by it, was the Page patent, since sustained by his Honor Judge Blatchford, in the United States Circuit Court for the Southern District of New York.

The result of that settlement has been that all the telephones formerly put out by the opponents of the Bell company, amounting to upwards of 30,000, are now paying royalty to it under license from it. More than three hundred cities and towns in the United States had telephone exchanges and reg-
183 ular organizations at the time I retired from business in the first half of 1881, and were engaged in furnishing to the pub-

lic speaking telephones under license contracts. Every telephone exchange in the United States and every organization publicly supplying telephones does so under licenses from the American Bell Telephone Company which expressly acknowledge the validity of the said two Bell patents, and under which they pay yearly royalties to the American Bell Telephone Company, owners of those patents.

As preliminary to the said contest between the Bell Telephone Company and the Western Union Telegraph Company 184
and its associates, the latter acquired all the inventions relating to speaking telephones made by Mr. Elisha Gray, Mr. T. A. Edison, and Mr. A. E. Dolbear, and caused said three persons to make applications for patents at the Patent Office; and these and other applications have led to a very large number of interferences, in which some of the thirteen claims of said two patents of Bell are involved. Only one of them—viz., that known as Interference A—involves the broad claim to the invention of the speaking telephone. The parties to this interference, at the time of the said settlement were Messrs. 185
Bell, Edison, Berliner, Gray, and Dolbear. Mr. George B. Richmond and Mr. Holcombe had been parties to it; but by decisions of the Patent Office, May 1, 1879, and July 29, 1879, the claims of the last two to priority were disallowed, and from this decision no appeal was taken.

The inventions of Mr. Berliner are owned by the Bell Telephone Company. His preliminary statement, filed in the Patent Office by him under oath, states that he did not direct his attention to speaking telephones until more than nine months after the date of Mr. Bell's first patent, and after he 186
well knew of it. His claim, in fact and as set forth in his application, is that he is the first inventor of a certain improved means of varying the resistance of an electrical circuit in order to accomplish the purposes which Mr. Bell's patent No. 174,465 says can be accomplished by varying this resistance, and for the ultimate purpose of transmitting sounds by the method referred to in the fifth claim of said Bell patent.

The inventions of Messrs. Edison, Gray and Dolbear were

owned by the Western Union Telegraph Company and their
187 associates at the time of the suit Bell Telephone Company *v.* Dowd, already mentioned, and as their applications with broad claims were pending in the Patent Office, the overthrow of Mr. Bell's patent upon prior inventions of either of those gentlemen who have given the Western Union Telegraph Company and their associates the ownership of the speaking telephone. But they did not suffice to enable the defendants to prevail in those suits. The reasons why they could not will appear from the dates proved by Mr. Bell (which are stated in his affidavit in this case), when compared with the statements made by those
188 inventors, among which are the following:—

Mr. Elisha Gray claims to be the first inventor of certain devices which know not of themselves constitute a speaking telephone, but which are said to be used in speaking telephones. I do not understand that the origin of these devices is material in the present case; The American Bell Telephone Company has, however, the exclusive right to use them in electric speaking telephones.

The only claim ever made for him as the first inventor of the speaking telephone rests upon a caveat filed Feb. 14, 1876.
189 He testified in the "Telephone Suits":—

"*Int.* 50. At the time of your filing your caveat, Feb. 14, 1876, had you ever seen or heard of any apparatus for the telephonic transmission of articulate speech other than that which you described and represented in that caveat?

"*Ans.* I had not."

His testimony and that of his assistant, Mr. Goodridge, do not give for the conception contained in that caveat any date earlier than Feb. 11, 1876, when he made a sketch of it and explained it to Mr. Goodridge (Goodridge, ans. 37, page 18,
190 Interference Record). The suggestion which lead to this conception came from a "Lover's Telegraph" or string telephone, which his assistant testifies was first shown him "in December, 1875" (ans. 96, page 71; ans. 172, page 108). Mr. Gray knew of Mr. Bell's patent 174,465 in March, 1876 (cross-ans. 103, page 137, "Telephone Suits"). He exhibited at the

Centennial his harmonic multiple telegraph inventions, and displayed them to the Emperor of Brazil and a distinguished group of judges, including Sir William Thomson and Professor Henry, on June 25, 1876; immediately afterwards Mr. Bell made the memorable exhibition of his electric speaking tele- 191
phone to the same persons, and Mr. Gray was one of those who took part in it and listened at Mr. Bell's receiver. Mr. Gray so testifies (cross-ans. 105–108, page 138, "Telephone Suits"). He also testified:—

"*Int.* 56. Was this apparatus which you saw at the Centennial the first one you ever saw in which an induction diaphragm was used in combination with an electro-magnet as a telephone transmitter?

"*Ans.* It was.

"*Int.* 57. Was such a combination for the purpose of a 192
telephone transmitter, new with Professor Bell, so far as you know?

"*Ans.* It was, so far as I know."

This combination constitutes the magneto-telephone transmitter.

After this for the first time, he attempted to make a speaking telephone transmitter, and constructed one in accordance with his caveat but did not succeed in transmitting speech by it. (Mr. Gray's ans. 12, page 45 of Inteference Record).

In connection with these dates of Mr. Gray's invention, as 193
stated by himself and his assistant, Mr. Goodridge, on the witness stand, I am requested to mention that it is apparent on the face of Mr. Bell's patent, 174,465, that the copy of the specification filed was completed and signed on or before Jan. 20, 1876, and was filed Feb. 14, 1876; and I constructed an electric speaking telephone, for Mr. Bell, and according to his direction in June, 1875.

In February, 1877, Mr. Gray delivered a lecture on telephony in McCormick Hall, Chicago. Before doing so he wrote to Professor Bell saying that he proposed to explain his own 194
(Gray's) system of musical or harmonic telephony, but would like, with Mr. Bell's permission, "to explain and exhibit your

method of transmitting vocal sounds as well, but do not feel at liberty to do more without permission from you. I should explain it as your method and not mine, though the Office records show a description of the talking telegraph filed by me the same day yours was filed. The description is substantially the same as yours." Mr. Bell answered that he might do so if he would refute some remarks in a Chicago paper
195 which seemed injurious to Mr. Bell's claims as the sole inventor. Mr. Gray replied:—

"I found the article I suppose you refer to in the personal column of the *Tribune*, and am free to say it does you injustice. I gave you full credit for the talking feature of the telephone, as you may have seen in the Associated Press despatch that was sent to all the papers, in the country, in my lecture in McCormick Hall, Feb. 27. There were four different papers represented at the lecture, but only one—the *Tribune*—alluded to my mention of you except the 'Press' despatch. I described
196 your apparatus at length by diagram.

"Of course you have had no means of knowing what I had done in the matter of transmitting vocal sounds. When, however, you see the specifications, you will see that the fundamental principles are contained therein. I do not however, claim even the credit of inventing it, as I do not believe a mere description of an idea that has never been *reduced* to *practice* in the *strict sense* of that phrase should be dignified with the name 'invention.'

"Yours very truly,
197 "ELISHA GRAY."

A report of that lecture in the Chicago *Tribune*, and testified to by Mr. Gray as substantially correct (ans. 136, page 146), showed that after Mr. Gray had completed the description of his own inventions in harmonic telegraphy, he referred to the speaking telephone and attributed the invention of it to Mr. Bell. The report says:—

"Another development of the telephone was interesting in a scientific point of view. Professor Bell in his investigations, had gone a step beyond composite tones, although they were

embraced in it and developed the transmission of vocal 198
sounds."—" Telephone Suits," page 177.

April 2, 1877, and while Mr. Bell was engaged in lecturing on his speaking telephone, Mr. Gray lectured in New York on his own harmonic telephone, and in that lecture he said substantially as is reported in the New York *Tribune* of the following day, viz:

" After the first part of the programme had been executed, Mr. Elisha Gray came forward and addressed the audience. He was aware that great confusion existed in the popular mind as to what this telephone could perform; in particular, it had 199
been confounded with the speaking telephone invented by Professor A. Graham Bell, of Boston. Professor Bell, Mr. Gray said, was present in the audience."—Telephone Suits," page 156.

I was at this time engaged with Mr. Bell, and knew of these occurrences and these letters. These letters and reports of lectures will be found as parts of Mr. Gray's cross examination in the " Telephone Suits." I never heard that Mr. Gray was, or was to be, put forward as the first inventor of the electric speaking telephone, until after and in connection with the at- 200
tempt of the Western Union Telegraph Company to manufacture and use telephones, as I have stated, and after they had acquired the control of all his inventions relating to electric speaking telephones. His application for a patent was filed Oct. 27, 1877, more than twenty months after the grant of Mr. Bell's first patent, nine months after the grant of his second one, and at a time when we had several thousand telephones in use under license and paying royalty.

Mr. Dolbear was examined as a witness in the telephone suits. He testified (p. 286):— 201

"*Int.* 4. When did you first turn your attention to the subject of the speaking telephone, and when did you first make a record of the results of your thought upon that subject?

"*Ans.* My first attention to the telephone that I have any memory of now was in August, 1876, at which time I made some experiments bearing upon that subject."

He testified that he had made previously some experiments as to the transmission of sound, but says as to them (p. 287), "The result was that the sounds transmitted were only those
202 of the pitch of the voice, and not articulate speech."

Feb. 16, 1877, he wrote to Professor Bell the following ("Telephone Suits," p. 299):—

"Professor A. G. BELL:

"*Dear Sir*,—The other day I visited your room at Exeter Place, and was kindly shown your invention the telephone, by Mr. Watson. . . . . I congratulate you, sir, upon your very great invention, and I hope to see it supplant all forms of existing telegraphs, and that you will be successful in obtaining the wealth and the honor which is due you.

203 "Yours truly,

"A. E. DOLBEAR."

I am the Mr. Watson referred to in the letter. Professor Dolbear did not then nor at any time claim to be an inventor of the speaking telephone. The only claim which he has made, and the claim set forth in an application filed on his behalf in the Patent Office, Oct. 29, 1879, after he had sold his inventions to the Gold and Stock Telegraph Company, was to certain improvements shown in Mr. Bell's second patent 186,787, of Jan. 30, 1877; viz., the use of a permanent magnet.
204 That this is the whole claim he has ever made is explicitly stated in his sixty-fourth and sixty-fifth cross answers, p. 300 in which he limits his claim to the improvement set fourth in the eighth claim of Mr. Bell's said patent 186,787.

In his deposition (ans. 4) and in his preliminary statement he gives the date of the conception of this as Sept. 20, 1876, and says that the instrument which first embodied it was completed and first tried in "the last part of January or first part of February, 1877." This invention was described by Mr. Bell in a specification prepared in the United States and filed
205 in the English Patent Office, Dec. 9, 1876. It is a matter within my personal knowledge that a permanent magnet telephone was made for Mr. Bell, and in accordance with his in-

vention, in July, 1876. I used it with Mr. Bell to transmit speech between Boston and Cambridge, in October or November, 1876, and I believe that he had used it before that.

A metallic diaphragm for a receiver was used in the instrument of Mr. Bell, at the Centennial, in June, 1876. This receiver was the one used by the judges and Mr. Gray, June 25, 1876, and is described in the judges' report.

A metallic diaphragm especially intended for a transmitter 206
was made by me for Mr. Bell under his directions, in June, 1876, and used by me, with him, as a transmitter for articulate speech, about the first of July, 1876.

In December, 1879, Mr. William L. Voelker, of Morton, Pa., was put into interference with Mr. Bell, upon an application filed in the Patent Office May 19, 1879, nearly three years after Mr. Bell's public exhibition at the Centennial, and at a time when there were more than 30,000 telephones in use paying royalty to Mr. Bell's assignees.

Mr. Voelker's preliminary statement says that he commenced 207
his experiments on telephones about Christmas, 1875, and completed his first telephone in March, 1876. In his deposition (p. 19) he says, "I conceived the idea, which is the point of this controversy, during the month of January, 1876. I carried it into practical shape the latter part of February or beginning of March of the same year."

Mr. Bell's patent shows that his completed specification was signed Jan. 20, 1876, and filed Feb. 14, 1876.

If the instrument constructed by Voelker were a speaking telephone, the dates he names would not anticipate Mr. Bell. 208

It was, however, expressly adjudged by experts who examined it for Mr. Voelker at the time, to be not distinguishable from the Reis circuit breaker, and Mr. Voelker has so testified in terms.

Mr. Edison's telephonic inventions were owned by the Western Union Telegraph Company and the American Speaking Telephone Company at the time said corporations defended said suit, and his name was mentioned in the answer as one who was the first inventor of something covered by some of

209 Mr. Bell's thirteen claims. I understood that the practical recognition of Mr. Bell as the first inventor of the electric speaking telephone, which was involved in the submission to the claim made by the complainants, was based upon the knowledge that nothing he had done could antedate Mr. Bell's said invention.

In 1878, and during the contest between the Bell Company and the Western Union and Gold and Stock Telegraph Companies, Mr. George B. Prescott, electrician of the Western Union Telegraph Company, vice-president of the Gold and
210 Stock Telegraph Company, and director of the American Speaking Telephone Company, published the first edition of a book called "The Speaking Telephone," etc., and in 1879 he published a second edition of it. Chapter VI. of that book is entitled "Edison's Telephonic Researches," and begins as follows (page 218):—

"The following communication from Mr. Thomas A. Edison gives a detailed account of his researches in telephony, and is a valuable contribution to the history of the speaking telephone:—

211 "'Some time in or about the month of July, 1875, I began experimenting with a system of multiple telegraphy which had for its basis the transmission of acoustic vibrations. Being furnished at the same time by Hon. William Orton, president of the Western Union Telegraph Company, with a translated description from a foreign scientific journal of Reis's telephone I also began a series of experiments with the view of producing an articulating telephone, carrying on both series simultaneously by the aid of my two assistants, Messrs. Batchelor and Adams.'"

It is not stated expressly whether Mr. Edison did or did not
212 invent or construct a speaking telephone before the date of Mr. Bell's patent; but I understand from the foregoing extract that it was not until in or about July, 1875, that he turned his attention to the subject. The dates already given show that Mr. Bell had preceded this. It appears from statements made on page 223 of the same communication that the form of trans-

mitter with which Mr. Edison's name is chiefly or solely connected was first devised by him in 1877.

The manufacture of the instruments made under license from Mr. Bell was under my personal supervision. The Bell company has taken extreme pains to construct them of the best 213
forms, and with all the improvements best suited to practically carry out the method set forth in the fifth claim of Mr. Bell's patent 174,465, and have made a very large number of experiments for this purpose. They have followed with great success the line of improvement marked out by Mr. Bell in his patent No. 186,787, of Jan. 30, 1877; that is to say, they use a diaphragm of inductive metal, an electro magnet with a short coil surrounding a small, soft iron core, permanently magnatized by induction from a compound permanent magnet to which it is fastened. They surround the diaphragm with a case which 214
encloses the rear part, and leaves in front a narrow and thin air space, with a hole in the centre to speak into or listen at. Most of the telephones used in England and some other foreign countries up to the date of my retirement were made in Boston under my supervision.

One of the most important improvements introduced is a "variable resistance" "battery telephone" or "voltaic transmitter," which produces on the line wire and in the receiver electrical undulations corresponding in form to the sound waves produced by the voice of the speaker, and does this by utilizing the movement given to the transmitting diaphragm 215
by those waves, to vary the resistance of a circuit exterior to a battery which supplies it with a constant electro-motive force.

The form of battery transmitter most in use was devised by Mr. Francis Blake, Jr., and is known as the "Blake transmitter." Mr. Blake was an officer of the United States Coast Survey, and in charge of the electrical determination of longitudes. After he had invented this instrument, he recognized that its use was covered by Mr. Bell's first patent, the validity of which he also recognized; and he brought it to the Bell 216
company, disposed of it to them, and has since become a director of the company. It is one of the class that operate to vary

the resistance of a battery circuit by the variations of resistance due to variations of pressure between two electrodes constantly in contact, one of which is acted upon by the diaphragm vibrated by sound waves, while the other, carried on a weighted spring acts as an anvil.

More than 100,000 of them have been made, licensed and put out under full royalty by the Bell company. They are all
217 licensed under the said Bell patents, are marked as made under said patents, and are universally recognized and paid for as coming under said Bell patents.

The various forms of voltaic transmitting telephones, of which the Blake is the one most practically efficient, have always been recognized as coming under and as covered by Mr. Bell's said patent, 174,465. I will mention some instances of such recognition, in addition to Mr. Blake's action.

Among the inteferences formerly declared by the Patent Office, the first one, known as "A," set forth as the issue, in
218 substance, the electrical transmission of articulate speech by causing electrical undulations on the line wire corresponding to the sound waves in their character as well as in their frequency or pitch. As contestants the Office named Mr. Bell, referring to the fifth claim of said patent and to Gray, Edison, Holcombe, Berliner and Voelker, whose applications described and showed battery or voltaic transmitters alone.

In said suit against Dowd the only inventions and apparatus set up to antedate Mr. Bell's said claim were battery transmitters The transmitters most in use are of this character.
219 More than 12,000 of the transmitters in use by and under the Western Union Telegraph Company and its associates at the conclusion of said suit were battery transmitters with hard electrodes in contact, using no liquid, and of the form known as Edison carbon transmitters. In the settlements which I have referred to, these have all been treated as coming under said Bell patent, and transfers have been made, licenses taken and royalties paid accordingly.

Mr. Edison's form of telephone, commonly known as the carbon telephone, which operates by a variation of resistance

produced by the motion of the diaphragm, was used in trans- 220
mitting articulate speech between Philadelphia and New York before April 3, 1878, and an account of such use is found in the Philadelphia *Record* and Philadelphia *Times*, of April 3, 1878.

The said Edison telephone was publicly exhibited and used in Washington before the Academy and elsewhere, on April 15, 1878, and a full description and account of this is found in the Philadelphia *Press* of April 16, and in the Washington *Post* and *Star*, of April 19, 1878.

Before July 1, 1878, this form of telephone was publicly 221
used by the Gold and Stock Telegraph Company, and offered by them for public and general commercial use.

Public and Commercial use of Telephones with Metallic Diaphragms.

All the instruments used at the public exhibitions hereinbefore described, from Jan. 1 to April 1, 1877, had metallic diaphragms. In addition to that, I will state some other uses of telephones with metallic diaphragms:—

Mr. Bell's magnet receiver, used as part of his speaking tele- 222
phone apparatus, exhibited and used at the Centennial Exposition, had a diaphragm entirely of soft iron. One like it, with a soft iron diaphragm, was given by him to Sir William Thomson and described by that gentleman in his address before the British Association in August, 1876, a copy of which, taken from the Boston *Daily Advertiser* of Sept. 25, 1876, has already been given. A description of the same, with woodcuts of it in a damaged condition, is in the *Scientific American* supplement of Feb. 10, 1877. These woodcuts are reproduced in Mr. Prescott's book on the "Telephone," page 101, in a reduced 223
size, and are given on p. 83, *supra*. This thin metallic iron disk, in combination with the electro-magnet, is also described as the receiver used at the Centennial in the official report on awards, prepared by Sir William Thomson, already quoted on p. 79, *supra*. I have already described and given some newspaper accounts of the use of Mr. Bell's telephone between Bos-

ton and Cambridge in October, 1876. Metallic diaphragms were then used in those instruments.

The instruments exhibited in operation before the Washington Philosophical Society, Jan. 13, 1877, had metallic dia-
224 phragms. An extract from a report of this in the Washington *Evening Star* of Jan. 20, 1877, has already been given.

All the telephones, the use of which has been mentioned in this affidavit as occurring after that date, had metallic diaphragms. Among the uses of those telephones with metallic diaphragms, which took place in the presence of a large number of persons and received publicity through the newspapers, I mentioned the following, which are already referred to in this affidavit:—

Report in Boston *Evening Transcript* of Feb. 1, 1877; re-
225 port of lecture at Salem, Feb. 12, 1877, was transmitted by telephone, and was transmitted and received in the presence of a large number of persons.

Another lecture at the same place, Feb. 23, 1877, was reported in the *Globe* of Feb. 24, 1877, the report being transmitted by telephone in the presence of a large number of persons. At all the subsequent lectures mentioned in this affidavit the public generally attended, paying admission fees; and a large number of the audience were at liberty to, and actually did, transmit and receive articulate speech through telephones with
226 metallic diaphragms. The character and construction of the diaphragm, and the fact that the *Globe* report was transmitted by it, is described and told in an extract from the *Globe* of Feb. 15, 1877, given on p. 100 of this affidavit. Such telephones were publicly used in New York, May 11, 1877, and a description of the use and of the instrument, mentioning the iron plate, was given in the New York papers of the next day; an extract from the *Tribune* report has been given on pp. 111, 112, 113, *supra*.

Other public uses of the speaking telephone with metallic diaphragms were made in New York, May 17, 18 and 19, 1877,
227 and reports of their use are in the New York papers of the next day. These reports stated that the audience publicly transmitted and received speech by them.

PUBLIC AND COMMON COMMERCIAL USE OF TELEPHONES.

I make the following statement as to the commercial use of electric speaking telephones, and as to the commercial recognition of Mr. Bell as the inventor, and as to the validity and controlling effect of his patents.

Mr. Bell and his associates made an arrangement with Charles Williams, Jr., of Boston, for the manufacture of his telephones with metallic diaphragms for general commercial 228
use some time previous to April 1, 1877.

An arrangement was made prior to April 1, 1877, by which Mr. Williams also obtained the right to supply the public with telephones made under Bell's patents for "private lines." He was to be allowed a commission on all he leased.

Before April, 1877, a line of wire was built from Boston to Somerville, for the express purpose of being used with telephones. It is correctly described in the following newspaper extract:—

BOSTON DAILY ADVERTISER. 220

APRIL 5, 1877.

"The first telephone line that was ever established has just been constructed between the office of Mr. Charles Williams, electrician, in this city, and his house in Somerville, and a conversation can be carried on with perfect distinctness. Mr. Bell was in New York on Tuesday evening, and conversed readily over the regular wires with parties in this city. He lectures in Providence this evening, on Telephones"

BOSTON POST.

THURSDAY MORNING, APRIL 5, 1877. 230

"The telephone has been put into practical use; yesterday a line was opened from the office of Charles Williams, Esq., 109 Court Street, to his house in East Somerville. The great value of this invention is thus manifested, for by its uses Mr.

Williams is now able to converse with his family when separated from them by fully three miles of distance."

THE BOSTON DAILY GLOBE.

APRIL 5, 1887.

"PERFECTING THE TELEPHONE."

231 "Professor A. Graham Bell, the inventor of the telephone, had the pleasure of assisting at the opening of the first regular telephone line in the world, a private line between the place of business of a gentleman in this city and his residence in Somerville. The instrument worked admirably, and the enterprising gentleman is very much pleased with his private telephonic wire between town and home. The practical value of Professor Bell's invention is being newly proved every day.

"While the Professor was in New York recently, he communicated with his associate in Boston, Mr. Watson, and the 232 telephone transmitted conversation over 280 miles of space with wonderful clearness and distinctness of sound."

THE BOSTON HERALD.

APRIL 5, 1877.

"The first telephone line ever established has just been constructed between the office of Mr. Charles Williams, electrician, in this city, and his house in Somerville."

THE BOSTON TRAVELLER.

APRIL 5, 1877.

"The first telephone line ever established has just been con- 233 structed between the office of Mr. Charles Williams in this city and his house in Somerville."

The telephones used on this line had metallic diaphragms. The owners of Mr. Bell's patents were about to manufacture largely for general commercial use, and this line was constantly used for the public to talk over that they might be induced to

buy or hire telephones. Such use by the public was made largely in April, 1877.

Between April 20 and 30, 1877, a line was built connecting the laboratory of Professor Bell, No. 5 Exeter Place, with the office of Charles Williams, Jr., No. 109 Court Street; 234
and, about the same time, telephone connection was made between said laboratory and the office of Stearns & George, 37 Pearl Street. These lines were specially erected for the business convenience of the parties interested, and were fitted up with telephones, all of which had metallic diaphragms.

JOURNAL OF THE TELEGRAPH.

APRIL 16, 1877.

"The first regular telephone line has been put in operation between the place of business of Mr. C. Williams, 109 Court Street, Boston, Mass., and his residence in Somerville, a dis- 235
tance of about three miles. Mr. Williams states that it works well, and that 'conversation can be carried on by it nearly as well as if in the same room.'"

About May 1, 1877, telephones with metallic diaphragms were put on a line connecting the office of Stone & Downer, 28 State Street, Boston, with the residence of one of the parties in Somerville, concerning which they addressed the following letter to Mr. Gardiner G. Hubbard, who at that time had charge of the business interests under the Bell patents:—

"OFFICE OF STONE & DOWNER, CUSTOM HOUSE BROKERS AND FORWARDERS, DEALERS IN SPECIE, GOVERNMENT BONDS AND STOCKS, EXCHANGES ON THE PROVINCES AND SAN FRANCISCO, 28 STATE STREET, BOSTON, MAY 14, 1877. 236

"GARDINER G. HUBBARD, Esq., Cambridge, Mass.:

"*Dear Sir*,—In reply to your inquiry regarding the use of the telephone, I would state that we placed them on our line between Boston and North Somerville some two weeks ago; we have used them constantly since with good success; in fact, we have become so used to them that we use them in prefer-

237 ence to the 'Morse System,' being able by the use of the telephone to transmit our messages much faster, and with a great deal less labor. We have experimented several times with musical instruments, and in each case have been attended with remarkable success; the playing of a piano being heard very distinctly, and no difficulty experienced in distinguishing the piece being played. We can certainly indorse the telephone as a success, and believe it can be used practically with many advantages over the old system of telegraphy.

"Yours, respectfully,

238 "R. C. & F. W. DOWNER."

The inquiry of Mr. Hubbard referred to in said letter was with the view of drawing out a reply from the Messrs. Downer for publication, in a circular then in course of preparation, and which was immediately thereafter printed for general circulation and widely distributed, which circular was in the following words:—

"THE TELEPHONE.

"The proprietors of the telephone, the invention of Alexander Graham Bell, for which patents have been issued by the
239 United States and Great Britain, are now prepared to furnish telephones for the transmission of articulate speech through instruments not more than twenty miles apart. Conversation can be easily carried on, after slight practice, and with the occasional repetition of a word or sentence. On first listening to the telephone, though the sound is perfectly audible the articulation seems to be indistinct; but, after a few trials, the ear becomes accustomed to the peculiar sound, and finds little difficulty in understanding the words.

"The telephone should be set in a quiet place, where there
240 is no noise which would interrupt ordinary conversation.

"The advantages of the telephone over the telegraph for local business are:—

"*First.* That no skilled operator is required, but direct

communication may be had by speech, without the intervention of a third person.

"*Second.* That the communication is more rapid, the average number of words transmitted a minute by Morse sounder being from fifteen to twenty; by telephone from one to two hundred.

"*Third.* That no expense is required, either for its operation, maintenance or repair. It needs no battery, and has no complicated machinery. It is unsurpassed for economy and simplicity. The terms for leasing two telephones for social purposes, connecting a dwelling-house with any other building, will be $20 a year,— for business purposes $40 a year, — payable semi-annually in advance, with the cost of expressage from Boston, New York, Cincinnati, Chicago, St. Louis or San Francisco. These instruments will be kept in good working order by the lessors, free of expense, except from injuries resulting from great carelessness.

"Several telephones can be placed on the same line at an additional rental of $10 for each instrument, but the use of more than two on the same line where privacy is required is not advised. Any person within ordinary hearing distance can hear the voice calling through the telephone. If a louder call is required, one can be furnished for $5.

"Telegraph lines will be constructed by the proprietors if desired. The price will vary from $100 to $150 per mile; any good mechanic can construct a line. No. 9 wire costs 8½ cts. a pound, 320 pounds to the mile, 34 insulators at 25 cts. each; the price of poles and setting varies in every locality; stringing wire $5 per mile, sundries $10 per mile.

"Parties leasing the telephones incur no expense beyond the annual rental and the repair of the line wire. On the following pages are extracts from the press and other sources relating to the telephone.

GARDINER G. HUBBARD,

"MAY, 1877. "Cambridge, Mass.

"For further information and orders address Thos. A. Watson, 109 Court St., Boston,"

In addition to the foregoing this circular contained a long extract from the reports on awards of the judges of the Centennial Exhibition, Sir William Thomson, chairman; a series of resolutions adopted by the Essex Institute, Feb. 19, 1877, relative to the telephone; an extract from the Providence *Evening Press* of March 19, 1877, giving an account of successful experiments by Professor Bell in talking through the telephone over a line forty-three miles long; an extract from the New York *Herald* of May 12, 1877, giving a description of an ex-
245 hibition by Professor Bell at the St. Denis Hotel, and the letter of Messrs. R. C & F. W. Downer, above given in full. In the New York *Graphic* of Wednesday, May 23, 1877, appeared the following article relative to the practical use of the telephone, from which it is evident that this circular had at that date reached New York:—

THE DAILY GRAPHIC, NEW YORK.

WEDNESDAY, MAY 23, 1877.

"The telephone is quickly working out a practical applica-
tion. A Boston company is prepared to furnish telephonic
246 communication between places not over twenty miles apart. The advantages are thus set forth; no skilled operator employed; a little practice makes any one master of the telephone; communication more rapid, the telephone transmits one or two hundred words per minute; the old telegraph apparatus averages not more than twenty; no expense required in its operation; no battery needed; two telephones connecting two houses may be leased for $20 per year. The company keep the instruments in working order. It must be understood that the rental mentioned above is for the use of the tele-
247 phonic instrument. A telegraph line, when required, will cost from $100 to $150 per mile."

In the early part of May 1877, an arrangement was made with the Cambridge Board of Water Works for putting up telephones on a line connecting their office in Cambridge with the works at Fresh Pond. This practical use of the telephone for public purposes was referred to as follows, in a Boston newspaper of May 19:—

THOMAS A. WATSON. 141

THE BOSTON HERALD.

MAY 19, 1877.

"PRACTICAL USE OF THE TELEPHONE. 248

"A telephone is to be placed in the City Hall, Cambridge, in the office of the Water Board, to establish communication with the water works at Fresh Pond. A line of wire has been constrncted, it being originally intended for the use of the printing telegraph. At the suggestion of Hon. Gardiner G. Hubbard, a telephone is to be substituted, that gentleman guaranteeing that the city shall be subjected to no expense unless the machine proves satisfactory."

BOSTON DAILY ADVERTISER.

249

MAY 19, 1877.

"THE FIRST PRACTICAL APPLICATION OF THE TELEPHONE.

"The Water Board of Cambridge has decided to have telephone communication with the water works at Fresh Pond, in order to facilitate the sending of messages. The Board has accepted the offers of Mr. Gardiner G. Hubbard to place the telephone in operation, the city to be at no expense unless the arrangement proves satisfactory. Mr. Hubbard was formerly President of the Board and feels interested in having Cambridge first to apply the wonderful invention to public service."

In the early part of May, 1877, telephones with metallic diaphragms were put up on lines, connecting the office of E. T. Holmes, Washington Street, Boston, with the banking house of Brewster, Bassett & Co., Congress Street, and the office of Charles Williams, Jr., 109 Court Street. These lines were intended to demonstrate the value of the telephone in connection with the burglar and fire-alarm systems of Mr. Holmes, and a public exhibition of the same was given on the seventeeth day of May following, notice of which appeared in a Boston newspaper the next day. The telephones used on that line had metallic diaphragms. 250 251

BOSTON EVENING TRANSCRIPT.

MAY 18, 1877.

"THE TELEPHONE.

"Another successful series of experiments with the telephone was made yesterday afternoon at the rooms of Professor Holmes, electrician, on Washington Street. At this place Mr. T. M. Carter played several cornet solos, which were distinctly heard at the rooms of Messrs. Brewster, Bassett & Co., on Congress Street, at a branch office on Court Street and in Somerville.

252 "In response, Mrs. Williams sang several songs in Somerville, which were plainly heard at these points above mentioned in this city. And singing from the Court Street office was heard in all the other places. Conversation was also carried on between the several points connected, with perfect ease."

On the eighteenth day of May, 1877, I personally put up a telephone in the office of H. L. Roosevelt, No. 40 West 18th Street, New York, connecting with another telephone supplied by Professor Bell at said Roosevelt's residence, both of which had metallic diaphragms.

253 On Monday the twenty-first day of May, 1877, in pursuance of an arrangement made some time prior thereto, I put up telephones with metallic diaphragms, on a line in Altoona, Penn., going from New York specially for that purpose.

All the lines above referred to as erected in April and May, 1877, were put up for practical business purposes, and were so used from the date of their construction.

During the months of April and May, 1877 Mr. Hubbard was constantly negotiating for the disposal of exclusive privileges, territorial licenses, etc., under the Bell patents, and for
254 supplying telephones with metallic diaphragms for commercial use. In April, or before, we made an agreement with Charles Williams Jr., and the firm of Stearns & George, by which these parties acquired a right to the private line telephone business for Boston and vicinity within a radius of ten miles.

Before May 1, 1877, said Hubbard was negotiating with Charles A. Cheever and others to supply telephones to them

for general commercial use in New York City; with Russell & Kinsman for their use in Boston; with E. T. Holmes for use of the telephone in Boston in his bank and express business; and with a great number of parties whose names I do not now 255
recall, for territorial privileges in various parts of the country. The offers made to these persons by Mr. Hubbard in April and May were to furnish telephones to them to be used on lines, which they were to put up for any customer who might apply. The circular already quoted and dated May, 1877, was advertised and made public some time prior to May 16, 1877. I fix that date as follows:

The circular was prepared by Mr. Gardiner G. Hubbard, Mr. Bell's business manager, and an abstract from the circular was published in the New York *Graphic*, of May 23, 1877, a copy 256
of which has been already given. These circulars were sent out by Mr. Hubbard from Boston; and as Mr. Hubbard had left Boston on May 16, to attend the lectures of Mr. Bell in New York on the 17th, 18th and 19th, and on the 20th went to Altoona, Penn., with me, to put up telephones, and went directly from Altoona to Washington, I am certain they were mailed before he left Boston.

I put up a set of electric speaking telephones with metallic diaphragms at Altoona, Penn., Monday, May 21, 1877, for Mr. Gardner, superintendent of the Pennsylvania Railroad. 257

The arrangement for them was made before Mr. Hubbard left Boston, May 16, 1877; I received my instructions May 18 or 19 to go to Altoona and put them up.

The arrangement for telephones for the Cambridge Water Board was made between Mr. Hubbard and the Water Board early in May, 1877. It was made before Mr. Hubbard left for New York, May 16, 1877; it is referred to in newspaper extracts of May 19, 1877, already given.

I put up a telephone myself for Mr. Roosevelt in New York May 18, 1877. Mr. Roosevelt put up the other. We imme- 258
diately used the line and it worked very satisfactorily. I am able to fix the date, May 18, 1877, as the telephones were put up during the New York lectures, already mentioned; and the

first and last days, the 17th and 19th, I was too busy to do anything but attend to preparations for the lectures.

The diaphragms in all instruments furnished after Jan. 1, 1877, were composed entirely of soft iron.

The extracts from the *Advertiser* and the *Globe*, of April 5, 1877, hereinbefore given, refer to the transmission of articu-
259 late speech over the regular wires between New York and Boston a few days before. Such transmission took place as described. I was at the Boston end of the line and talked with Mr. Bell in New York.

The telephone used on that occasion was what was called a box telephone, consisting essentially of a large permanent magnet, with coils of wire on its ends and a diaphragm of soft iron, fastened on a wooden block behind a mouthpiece, and the whole covered with a thin wooden box. It is essentially like the drawing, defendant's Exhibit Bell Telephone A, p. 772, Vol. II
260 of the record in the Dowd case. That drawing, however, shows the instrument with its cover off in order to exhibit its interior. In practice a wooden cover like a box went over the whole interior part, which was screwed on to the base, and this is what gave it the name of box telephone. As we progressed the telephones were gradually made neater and smaller. Box telephone No. 39, a cut of which is hereinafter inserted, was made in June, 1877. In this the cores of the coils are prolongations of the magnet. They were afterwards placed on the side of the magnet, and the position of the diaphragm and mouthpiece
261 changed, so as to occupy the same position in relation to the cores as in No. 39. This much reduced the size of the instrument and allowed it to be screwed directly to the wall. The change was made about Aug. 1, 1877. Box telephone No. 251, a cut of which is hereinafter inserted, shows this change.

Those used at the lectures in the spring of 1877 were substantially like the exhibit, but were much larger. The first modification was to reduce the size of the box and magnet; then to change the position of the cores on the magnet, and about the middle of May, 1877, we began to make the form of
262 telephone known as the hand telephone. No. 10 of the manu-

facturer's series of hand telephones was made in the last of May or first of June. In this telephone the magnet is a solid single pole steel magnet, about four inches long. The core is about a quarter of an inch in diameter and half an inch long; formed by reducing the diameter of the steel magnet with a coil about three eighths of an inch long and one and a quarter in diameter of insulated wire. Resistance, sixty-five ohms. The diaphragm of thin soft iron about two inches in diameter. The whole is mounted in a wooden handle, similar in shape to a butter stamp, so that it can be easily handled. 263

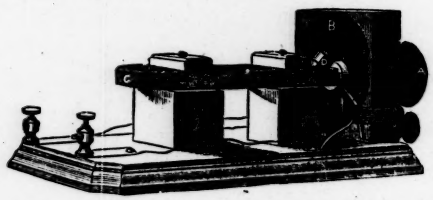
After this form, No. 10, we modified the shape of the hand telephone, making it a little larger and plainer shape, with a rather deeper flare at the mouthpiece. This change was made early in June, 1877. No. 18 of the manufacturer's series, a cut of which is hereinafter inserted, is one of this form.

About the middle of December, 1877, we gave up wood as a material for the handles of hand telephones, and adopted hard rubber of substantially the form now in use.

About the middle of August, 1877, we changed from single bar magnets to compound bar magnets made up of several 264 layers of magnetized steel, which was stronger and easier to magnetize than the single bar magnet.

I insert, as part of this affidavit, cuts of box telephones "A," "39" and "251," and of hand telephones "10," "18," and the form in use since Dec. 1877.

BELL TELEPHONE "A," PAGE 772 OF DOWD CASE.

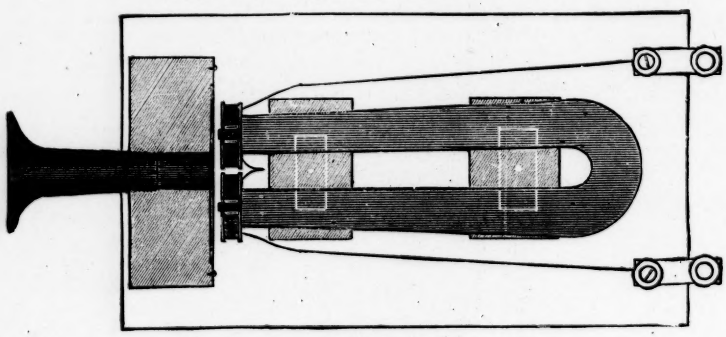


A. Speaking Tube. C. Permanent Magnet.
B. Metallic Diaphragm. D. Signal Call.

DIMENSIONS.

265	Length of permanent magnet	$7\frac{1}{4}$ inches.
	Length of spool	$\frac{3}{8}$ "
	Diameter of spool	$1\frac{1}{8}$ "
	Diameter of diaphragm	$4\frac{1}{4}$ "
	Length of speaking tube	$3\frac{1}{4}$ "

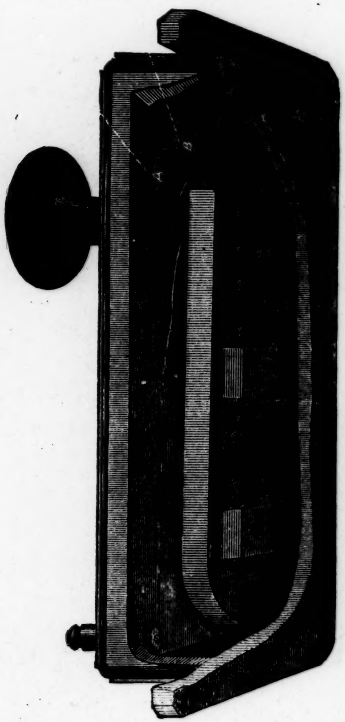
BOX TELEPHONE "No. 39" OF JUNE, 1877.



DIMENSIONS.

	Length of permanent magnet (including core)	$7\frac{5}{8}$ inches.
	" spool	$\frac{1}{4}$ "
	" core	$\frac{5}{16}$ "
266	Diameter of spool	$1\frac{1}{8}$ "
	" core	$\frac{1}{4}$ "
	" diaphragm	$4\frac{3}{16}$ "
	" sound chamber	$3\frac{3}{8}$ "
	Depth of sound chamber	$\frac{1}{16}$ "

BOX TELEPHONE "No. 251" OF AUGUST, 1877.



A.—Diaphragm broken off to show sound chamber.

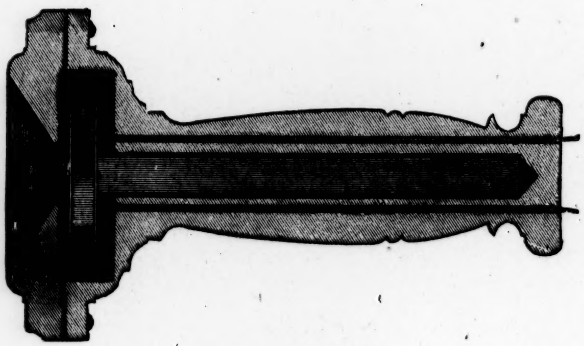
B.—Sound chamber.

DIMENSIONS.

Length of permanent magnet	7	inches.
" spool	$\frac{3}{8}$	"
" core	$\frac{7}{16}$	"
Diameter of spool	1	"
" core	$\frac{1}{4}$	"
" diaphragm	$4\frac{1}{8}$	"
" sound chamber	$3\frac{3}{8}$	"
Depth of sound chamber	$\frac{1}{16}$	"

267

HAND TELEPHONE "No. 10" OF MAY, 1877.

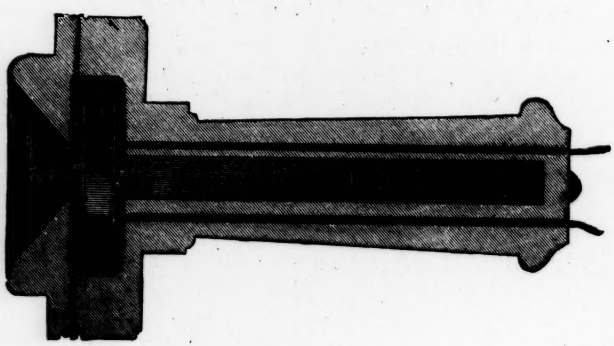


DIMENSIONS.

Length of permanent magnet	$4\frac{1}{4}$	inches.
" spool	$\frac{1}{4}$	"
Diameter of spool	$1\frac{1}{8}$	"
" diaphragm (in the clear) . .	$1\frac{3}{4}$	"

268

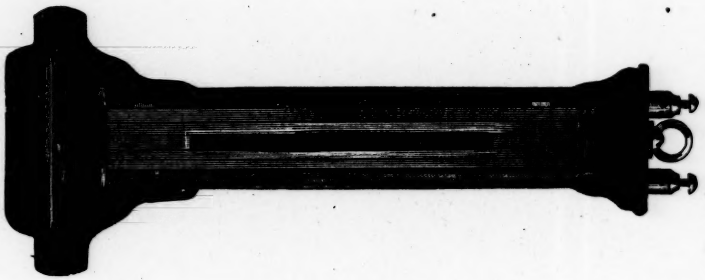
HAND TELEPHONE "No. 18" OF JUNE, 1877.



DIMENSIONS.

Length of permanent magnet . . .	$4\frac{1}{16}$	inches.
" spool	$\frac{1}{4}$	"
Diameter of spool	$1\frac{1}{8}$	"
" diaphragm (in the clear) . .	$1\frac{3}{4}$	"

RUBBER HAND TELEPHONE IN USE SINCE DEC., 1877.



DIMENSIONS. 269

Length of permanent magnet . . .	$4\frac{3}{4}$	inches.
" soft iron core	$\frac{9}{16}$	"
" spool	$\frac{1}{2}$	"
Diameter of spool	1	"
core	$\frac{1}{4}$	"
diaphragm (in the clear) . .	$1\frac{3}{4}$	"

By July 30, 1877, about 164 hand and 70 box telephones were in public use.

By Jnly 31, 1877, about 658 hand and 120 box telephones were in public use. 270

By Aug. 31, 1877, about 1000 hand and 300 box telephones were in public use.

By Oct. 31, 1877, about 3000 telephones of both descriptions were in use.

By June 1, 1879, this number had increased to over 33,000; by May, 1881, to over 100,000, and by July 1, 1882, (as I learn from the company's reports,) to over 200,000.

All of the telephones thus put into public use have had metallic diaphragms.

The owners of said Bell patents and their licensees have originated the system of telephone exchanges. At the time of my retirement such exchanges existed in more than three hundred and fifty cities and towns of the United States, all of which were under license and paying royalty to the owners of 271

said patents, and recognized the validity and controlling effect thereof.

By July 1, 1882, (as I learn from the reports of the company,) the number of telephone exchanges had increased to over 500.

From time to time, a few infringing telephones have been
272 found, but without mark or name to indicate their origin. The parties using them have uniformly, so far as I know, been notified to desist from using them, and have almost always done so at once. Where we have been able to trace the makers, suits have been brought, and further infringements stopped by decrees. It is practically very difficult to discover and trace infringing telephones. They are so simple in construction that tolerably efficient instruments can be made by any mechanic; they can be used on private lines or on a person's own premises, so that it is almost impossible to find them; even when
273 the users desist when notified, the expense of hunting for such infringements and tracing the instruments to their makers is great, and the makers when found are irresponsible persons, working secretly. Still I do not think that during the whole life of the patent, there have been as many infringing telephones used, except by the Western Union Telegraph Company, (whose use of them has been entirely stopped,) as are often put out by the Bell Telephone Company under license in a single week.

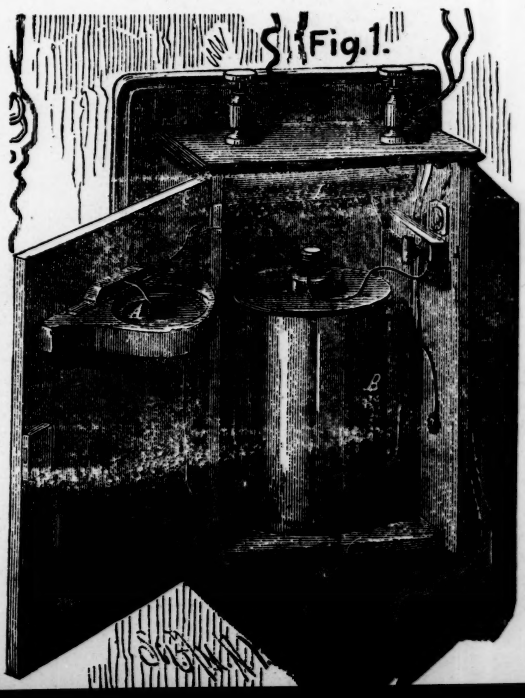
THOMAS A. WATSON.

Sworn to.

AFFIDAVIT OF EDWARD DAVIS.

[FILED OCT. 10, 1881.]

My name is Edward Davis; age, forty-two years; residence, Cambridge, Mass.; occupation, telegraph machinist. I am familiar with electric speaking telephones, and for three years have been exclusively engaged in the construction and repair of telephones and telephonic apparatus. I am acquainted with the receiving telephone recently patented by Prof. Amos E. Dolbear, which, with a microphone transmitter, was described at length in the "Scientific American" of June 18, 1881. A set of these instruments are, and for some time have been, in operation on a line connecting the office of F. M. Holmes, 107 Washington street, Boston, with the rooms of Prof. Dolbear, 70 Washington street, Boston. In the early part of July last these instruments were on exhibition, and many persons saw them and talked through them. I examined them at about that date. The transmitter used was similar to that shown in the articles in the "Scientific American" of June 18, 1881. The following figure, marked "Fig. 1," illustrates this instrument.



A is the diaphragm, which is about the size of that used in the Blake transmitter. It is clamped around the edge, and covers an air chamber, as shown in Fig. 2.

Fig. 2.

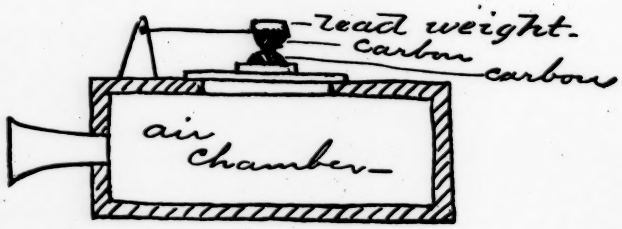
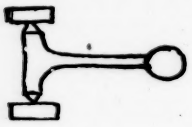


Fig. 3.



The contacts are both of carbon, and the upper one is weighted with lead and supported by a lever arm pivoted as shown in Figs. 2 and 3. One cell of battery is used similar to the Lechanté. The coil I (Fig 1) has a very low resistance primary, and a secondary of very high resistance. The receiver is shown in section in Fig. 4, and in perspective in Fig. 5. It consists of two diaphragms of

Fig. 4.

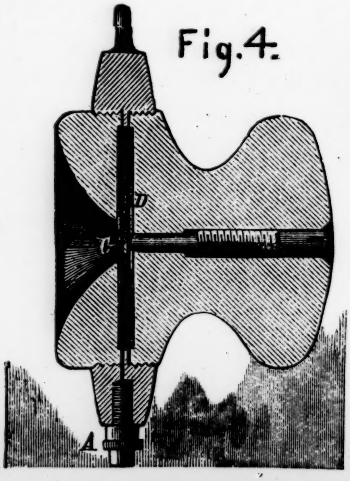


Fig. 5.

about the size and thickness of those used in an ordinary Bell telephone, mounted in a hard rubber frame R. R', with an intermediate space of about one twentieth of an inch between them. The adjusting screw S enables the distance between the plates to be regulated. The two diaphragms are connected to two binding screws, one of which connects to line and the other to earth, as shown in the accompanying diagram "Fig 6."

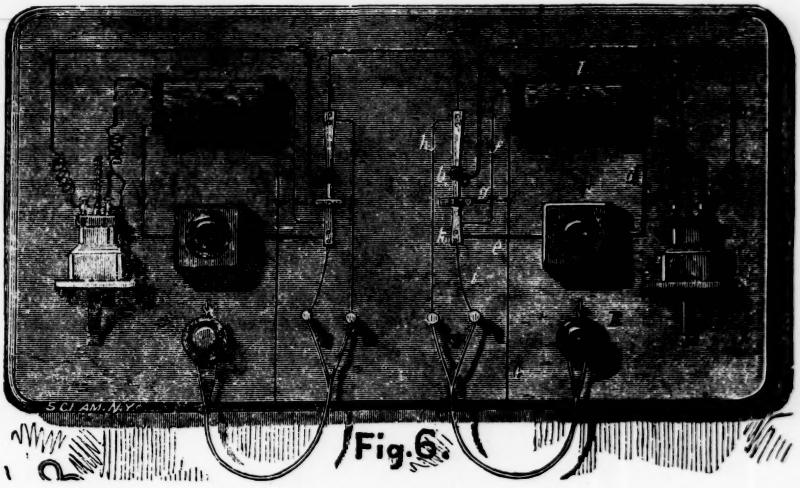


Fig. 6.

In talking, the key *k* is pressed down, and the primary circuit is from battery B by wire *p'* to coil I, then to transmitter T, then through *k* back to wire *p''* *p''* to battery. The secondary circuit is from earth by wire *s* up through the coil and then out through the key to line.

In listening, the key *k* is left up, and the current comes in from line through *h* to the receiver R, thence to *k* and by the little wire *g* to earth. I talked over the line, using the instruments referred to for speaking and listening, and found them adapted for the transmission of articulate speech.

These instruments were shown and explained to me by Mr. H. C. Buck, Prof. Dolbear's assistant, who also informed me that several sets of the Dolbear telephones were then in actual use, and that a company was about being formed for putting them extensively into public use.

EDWARD DAVIS.

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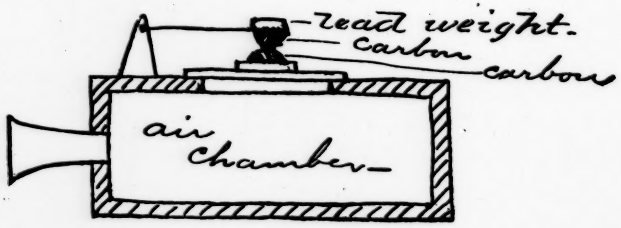
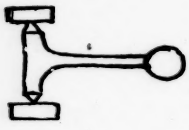


Fig. 3.



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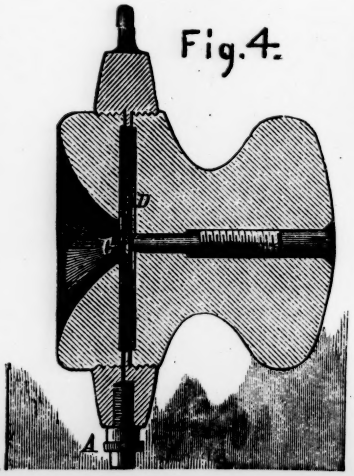

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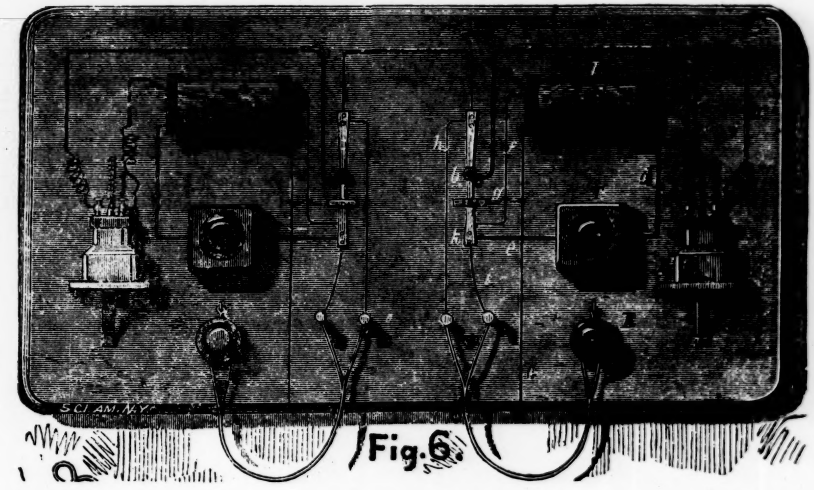

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EDWARD DAVIS.

178

STATE OF MASSACHUSETTS,
COUNTY OF SUFFOLK, ss.

Subscribed and sworn to before me this twelfth day of September, A. D. 1881.

GEO. WILLIS PIERCE,
Notary Public.

[SEAL]

AFFIDAVIT OF ALBERT H. CHAPMAN.

[FILED OCT. 10, 1881.

My name is Albert H. Chapman; my age is forty years; I live in Boston; I am an electrician. Last summer I was an agent for the Gold and Stock Telegraph Company in Boston. I now have charge of private telephone lines for the American Bell Telephone Company in Boston. I know Prof. Amos E. Dolbear of Somerville, Mr. F. M. Holmes and Mr. H. C. Buck, Mr. Dolbear's assistant, of Boston, and Mr. Henry B. Metcalf of Pawtucket, R. I. Early in July of this year I went to the workshop of Prof. Dolbear, 70 Washington street, Boston. I there met Mr. Dolbear and Mr. Metcalf, and talked with them. Mr. Buck was present, but I did not directly converse with him. Mr. Dolbear showed me a telephone transmitter fastened to the wall, and a receiver hung near it, and told me that they were connected by a wire with another set of instruments at the store of Mr. F. M. Holmes, 107 Washington Street, Boston. He told me that these sets of instruments were of his own construction and constructed by his direction, and that by them a conversation could be carried on. At his invitation I then did, by these instruments, carry on a conversation with some person who they said was at Mr. Holmes's store. This transmitter and receiver were opened and shown to me, and I saw their construction. They are like those described in the affidavit of Mr. Davis in this case. In addition to these instruments, there was another set which connected with a wire running to another part of the building, and which I understood was for experimental purposes. A conversation then took place concerning the manufacture and sale of such telephones. Mr. Metcalf said that he was interested in them, and that he and his associates proposed to construct them and

put them out to the public for general use, and that for that purpose they intended to get up a corporation. He said that Mr. Holmes was interested with them, and was the principal moneyed man. The probable cost of manufacturing them was discussed, and Mr. Metcalf said that he had figured what it would cost. We were all three sitting together, and Mr. Dolbear took part in the conversation and spoke of these plans substantially as Mr. Metcalf did. Both of them said that they should not be deterred by the patents of Mr. Bell from making and putting out telephones; that they should take the ground that their instruments were different from Mr. Bell's, though they expected that the Bell company would interfere, and that there would be litigation. The decision of Judge Lowell in the Spencer case was spoken of, and they expressed the opinion that it was wrong.

Sept. 15, 1881, I was again at Mr. Dolbear's same rooms. I there and then met Mr. Dolbear. We conversed about his telephones, and in the course of his conversation he said that he and his associates intended to make and put out his telephones, and that they should organize a company for that purpose as soon as Mr. Holmes returned; that Mr. Holmes was then out of town, but was expected shortly. The instruments were up, substantially the same as at my previous visit. They appeared to be the same as those described in the affidavit of Mr. Edward Davis in this case.

There is a telephone line from the furniture store of F. M. Holmes & Co., 107 Washington Street, Boston, to their furniture factory in East Cambridge. It is furnished with the telephones of the American Bell Telephone Company, and is used for the regular furniture business of the said Holmes & Co.; I understand that Holmes & Co. own the wire.

After I saw Prof. Dolbear, on Sept. 15, I went into Mr. Holmes's store and there saw a set of telephones fastened to the wall near the Bell telephones which connect with said line to East Cambridge. I recognized them as the Dolbear instruments, transmitter and receiver. The person in charge said that as soon as Mr. Holmes got home they would be connected to that line and used on it.

I again saw said Dolbear telephones at the same place in Mr. Holmes's store, Sept. 21, 1881. Another person who appeared to

be in charge of the room said that Mr. Holmes had been so busy that he had not time to connect them, but was going to connect them and use them right away.

On Oct. 6, 1881, I went to Mr. F. M. Holmes's warehouse, 107 Washington Street, Boston. The Dolbear instrument I formerly saw there arranged with the East Cambridge line had been removed, and the man in charge of the office said that they had been used, but did not work satisfactorily, and that Prof Dolbear had taken them to his laboratory, and he said he supposed they intended to bring them back. On the same day I saw Mr. F. M. Holmes at the same place. He told me that he and his associates intended to have started in the business of making and putting out telephones before this time, and expected to have got up a company for the purpose in the early part of July last; but that the assassination of the President had made them hesitate on financial grounds about putting out sufficient money to put the enterprise on such a basis as they intended. He said that now they intended to proceed and manufacture and put out telephones for general use and introduce them, and expected to do so very soon. He said that he considered that the Dolbear instruments were entirely different from the Bell instruments, and that he should not be deterred from going forward by any claim that his instruments infringed the Bell patents.

In speaking of what was intended to be done about the Dolbear instruments, he invariably used the pronoun "we," and I understood from him that he and others had joined in the enterprise to make them and introduce them.

ALBERT H. CHAPMAN.

UNITED STATES OF AMERICA,
DISTRICT OF MASSACHUSETTS, } ss.

Subscribed and sworn to this seventh day of October, 1881, before me.

WM. S. DEXTER, *Commissioner U. S. Circuit Court.*

AFFIDAVIT OF THEODORE N. VAIL.

[Filed Oct. 10, 1881.

I, Theodore N. Vail, a witness of lawful age, on oath depose and say: I am the general manager of the American Bell Telephone Company. I have been connected with the companies owning the Bell patent since June, 1878, as general manager.

I have read Mr. Watson's affidavit in this case. All the statements therein contained relating to matters during my connection with these companies are true. I was personally concerned in the settlements made by the Western Union Telegraph Company and others, in consequence of the Dowd suit.

Since the publication of the two patents of Mr. Bell, Nos. 174,465 and 186,787, it has been easy and inexpensive for any one (who had the right so to do) to make electric speaking telephones sufficiently good for practically useful work. The public appreciation of their utility, and the demand for their use, have been such that if no further improvements had been made in them, or in the arts directly connected with them, I am sure that large numbers would have been called for and used, at remunerative prices. But the present demand for them, and the extent of their use, are very largely due to the efforts which have been made to introduce them, and to perfect the appliances for, and organization of, the telephonic systems, of which the telephone itself is the essential and controlling part. Every pair of instruments now in use has required the construction of a line of wire, of call bells, alarms, switches and batteries. The telephonic exchange system requires the establishment of a system of wires leading from the subscribers' premises to a central office, the preparation of a central office, suitable provisions there in the way of elaborate and expensive switch boards, signals and other devices, by which any one of several thousand subscribers can, with the least possible delay, be put into direct and private communication with any other. Substantially all the apparatus in use for these purposes has been newly invented, or has been modified from old forms to meet these new demands. Many such improvements — to the amount of several hundred — have been patented; but a very large, and perhaps the most important part of

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ALBERT H. CHAPMAN.

UNITED STATES OF AMERICA,
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them, consist in modifications of form and of workmanship which, though not patentable, have been the result of careful and expensive experiments, in the course of which those engaged in them have been obliged to withdraw from use and condemn many thousands of instruments, not because they were not operative, but because others were better.

In addition to this, the manner of organizing and establishing the business, and particularly the establishment and operation of exchanges and lines in large cities, has been the subject of much study and expense in acquiring the needed experience. In the course of this, many systems of lines and apparatus have been discarded, and rebuilt or reconstructed. The knowledge and experience thus gained has been the most expensive, and perhaps, on the whole, has constituted the most important progress, of which the public and the persons concerned have had the benefit.

Substantially all this improvement has been made by the owners of Mr. Bell's patents and those who operate under them, or in direct connection with his licensees. As one item of expense, I will mention that one such corporation has expended more than $100,000 in instruments alone which have been condemned, because superseded by improvements. I am quite sure, from my knowledge, that the experience thus gained, and of which any person who can freely make and use telephones can have the benefit, has actually cost the licensees under the two Bell patents more than half a million dollars.

As nearly as I can ascertain (and my duties enable me to have as accurate information on this subject as any one), upwards of 100,000 signal instruments and switches have been manufactured and put into use on telephone lines; from 50,000 to 75,000 miles of telephone wire put up; telephone exchanges established in more than four hundred places, in every State in the Union, including nearly all the cities in the United States of over 5,000 inhabitants; and more than 160,000 telephones are in use on such lines and exchanges, under license from the said Bell patents.

Many million dollars of capital is represented by this business and embarked in it. The Bell company and its licensees have put in and actually expended in experiment and construction, in the

manner, and for the purposes I have stated, in actual cash, more than $3,000,000 in excess of the amount withdrawn in dividends since the business was established. I believe that if the protection of the patents under which they have embarked shall be continued, they will receive handsome returns for their outlay, and it has been made in this belief; but if the Bell patents are invalid much of this money would be lost. So long as the patents under which they have invested their money continue to be respected as they have been, the owners and licensees under them will be able to be remunerated for the expensive knowledge and experience which has been gained, because it all relates to or is auxiliary to the use of the patented telephones; but the character of what has been done is such that if protection cannot be had under those patents, and telephones can be used without license under them, the new-comers will largely reap the benefits of what has been gained at the expense of those who have spent their money, relying upon these patents for its return.

If by inability to obtain preliminary injunctions the manufacture and use of telephones should be practically thrown open to the public during the time which I am informed is needed to bring a suit on the patents to final hearing, I am of opinion that the evils to the present owners and licensees and the benefits to infringers, which I have above referred to, would be suffered and realized to a very great degree. This would be partly because of the derangement of the business, and partly because the manufacture of tolerably efficient telephones is so easy that the country would be full of irresponsible infringers.

From my knowledge of the business, I am satisfied that such general and unrestrained infringement for two or three years, at the present time, would take away nearly all the incentive to improvement and nearly all the means for improvement on the part of those who carry on the business, and thus the public would be less well served than they would be if the patents are respected.

The complainant has established a telephone exchange covering Boston and its vicinity, and has constrained a large number of private lines of leased telephones in this neighborhood. It has also, at large expense, provided itself with facilities for extending the said

business as fast as demanded by the wants of the public; and this business, which has been established for several years, has been seriously interfered with, and the complainant would suffer injury, which would be large and difficult to estimate, if infringing telephones should be made and used. In addition to that, the distribution of telephones among the community by the manufacturer would require and necessarily lead to a large number of suits and great expense and annoyance, both to the complainant and to those who might be guilty of such interfering use. From the nature of this instrument it would not be used by the manufacturer himself at his own factory, but would be provided for the purpose of being furnished to the general public, and so used by them.

I have heard of the telephonic apparatus constructed by Amos E. Dolbear, of Somerville, in Boston, and which is said to contain some improvements or devices which he claims to have invented. Some improvements of that kind are described in the patent No. 239,742, issued April 5, 1881, to said Dolbear, for "Apparatus for transmitting Sound by Electricity."

I have been informed and learn that recently said Dolbear and the defendant, Francis M. Holmes, and others, have associated themselves together for the purpose of manufacturing telephones, inducing others to manufacture them, and of causing them to be introduced into general use in the community, if they can succeed in doing so. June 18, 1881, a description of this apparatus, purporting to have been written by Mr. Dolbear himself, with illustrations, was published in the "Scientific American," a newspaper of large circulation, printed in New York, a copy of which is hereto annexed and made a part hereof.

I have also been informed that a line has been constructed from the establishment of Mr. Dolbear, No. 70 Washington Street, to the furniture warehouse of the defendant, F. M. Holmes; that the public have been invited to freely come and use said line, and that many persons have talked over it by means of speaking telephones constructed by said Dolbear, or under his direction, and connected with it; and that the purpose of said defendants in constructing and arranging said line and instruments, and inviting others to use them, is to facilitate their said scheme of introducing them into general

and public use. Said line, I am informed, has also been used by said Dolbear and said Holmes as a means of communication upon their own private business.

I have been informed that said Dolbear and said Holmes have solicited other people, and endeavored to induce other people to join them in their said scheme. I have also been informed that they are arranging to form a corporation, with large capital, for the purpose of manufacturing and selling, or otherwise furnishing to the community, such infringing telephones.

Part of my information on this subject is derived from the affidavit of Edward Davis; and the telephones described in said affidavit of Davis, when arranged in connection with a line and used for the transmission of speech, infringe the patents of Alexander Graham Bell, named in the bill in this case.

THEO. N. VAIL.

STATE OF MASSACHUSETTS,
COUNTY OF SUFFOLK, ss.

Subscribed and sworn to before me this twelfth day of September, A. D. 1881.

[SEAL.] GEO. WILLIS PIERCE,
Notary Public.

SCIENTIFIC AMERICAN DOLBEAR ARTICLE.

[AFFIDAVIT OF THEO. N. VAIL PAGE 118, *ante.*]

A NEW SYSTEM OF TELEPHONY.

BY A. E. DOLBEAR.

That rubbing a piece of amber will endow it with the property of attracting other bodies has been known from remote times, and it is probable that this phenomenon was the only electrical one known until comparatively recent times. Sulphur, wax, glass, and a few other substances were found to possess the same quality, and latterly it has been discovered that every substance whatever, when subjected to friction from a different kind of substance than itself, is capable of attracting light bodies in the same way as amber and as glass. The difference is one of degree only.

Another phenomenon due to the electrical excitement of bodies by friction is, they attract each other stronger than they attract other bodies, while each of the excited substances will repel a similar body excited in the same way.

But there are other ways of generating electricity that are familiar enough nowadays; for example, the galvanic battery; but this does not exhibit the attractive property of the piece of rubbed glass in a way that is appreciable by ordinary means. A well-excited piece of glass will make a pith ball to move toward it from a distance of a foot or more. But let the pith ball be brought very near to any part of a battery or a wire attached to a battery, and no appreciable motion will take place. If, however the wires connecting the terminals of the battery be wound into a helix that incloses a piece of iron, the latter will be made a magnet by the current of electricity in the wire, and this magnet will attract other bodies.

A very strong magnet will attract any body whatever, even a pith ball or a piece of hard rubber, but the strongest electro-magnet hitherto made will not attract such a substance to itself from a distance of half an inch. The attractive property manifested by the iron is

called *magnetism*, and the corresponding property of the glass that has been subject to friction is called *electrical attraction*.

While it is true that a current of electricity in the wire conductor of a battery is capable of developing an attractive property in the iron, it is also true that the terminal wires of the battery, when they are not connected, manifest an *electrical* attraction, for if they be properly connected to a sensitive electrometer the latter will show them to be electrified, one positively, the other negatively; and, in order to understand better what is subsequently stated it will be best to dwell a little while upon this phenomenon.

It has been stated above that all substances may be rendered electrical by friction, but for conductors of electricity like the metals friction is not essential; it is only necessary to *touch* one metal to another or to a fluid, like water, when one will be found positive and the other negative. Thus, if a piece of copper is touched to a piece of zinc the copper will be found to be positively electrified, and the zinc negatively; if the copper is touched to water the latter will be positive, and the copper negative; while if the zinc be touched to the water the latter will still be positive, but the zinc will be more negative than the copper was. Now these differences of electrical condition are called differences of potential, and difference of potential is electro-motive force, or the condition which results either in electrical attraction or in a current of electricity in a suitable conductor. A great number of facts lead one to the belief that whenever two different substances are placed in contact there an electro-motive force is developed, electricity is generated; and the probable explanation of this is that the atomic and molecular motions of two differently constituted bodies cannot be exactly alike; that is, they cannot be taking place at the same rate in both bodies. The molecules of a dense body cannot be moving as fast as those of a less dense body, and when these differently moving molecules are placed in contact with each other there must be some rearrangement of their motions at the points of contact, and the readjustment is quickly distributed by reaction throughout the whole body if it be what is called a good conductor, and more slowly in a poor conductor, but after such distribution there is no further action unless some means is provided for maintaining fresh surfaces

of contact. In the galvanic battery this is effected by the gradual solution of the zinc, by which the surface molecules are removed, thus presenting a fresh surface for renewal of the original conditions. As the electricity thus generated tends to go from the element with the higher potential to the lower one, there will be what is called a *current* through any conductor that connects them so long as the solution of the zinc goes on, but break the wire that connects the two metals and the current will stop, and the ends of the wires will be found to be electrified, one positively, the other negatively.

But electricity may be generated in other ways still, and the method discovered by Henry more than forty years ago is second to none in scientific interest as well as practical use. It is this: that whenever a current of electricity in a conductor is started or stopped, or in any way varied, another current will be generated in an adjacent conductor, but it will have a direction opposite to to that of the originating current. This is the foundation of what is now called *inductive coils* or inductoriums. These consist of two coils of wire, one with only a few turns of larger insulated wire wound over a bundle of iron wires, the other coil being wound outside of the first or primary coil, and consisting of a great many turns of very fine wire. The primary coil may be connected to a battery, as in Fig. 5, first page, while the terminals of the secondary coil are generally made fast to some hard rubber mounting, as in Fig. 7. When a current of electricity is permitted to traverse the primary coil the induced electro-motive force in the secondary coil raises one terminal to a higher potential than the other; that is to say, one terminal is positive, the other negative; and, if a wire connects these terminals, a current will flow through it from the positive to the negative terminal. If a galvanometer be connected to them the needle will be deflected by the current. Indeed, it is not necessary to have the wire terminals quite touch each other, for if the electro-motive force be great enough a spark will pass from one to the other, the spark being a part of a transient current, and consisting of some of the material of the terminal that has been torn off, and is transferred to the other terminal because it is electrified positively, and is, therefore, attracted by the other terminal, which is negatively electrificd.

That the terminals are electrified at such times may be proved by bringing a pith ball suspended by a thread near to one of them, or attaching one of the brass disks of an Epinus condenser by a wire to the terminal, as E in Fig. 5. Each make and break of the battery current will make the pith ball move toward the disk. This principle of the attractive power of an electrified body for other bodies is the basis of the new speaking telephone about to be described.

THE RECEIVER.

This consists in its simplest form, of two metallic disks about two inches in diameter, so mounted as not to be in metallic contact, and this is effected by turning a flange in a hard rubber case so they may be kept apart by it (see Fig. 4). A cap is screwed down upon each plate, one of them having a small hole in the middle of it to listen at; the other is a larger one, having a knob turned upon it for conveniently holding it in the hand. Through the middle of the knob a screw is sunk which touches the back plate and serves to adjust it to the best position relative to the front or vibrating plate. The back plate is thus fastened at both edge and middle, which prevents it from vibrating, while the front plate is only fast at its edge, leaving the middle free to vibrate. Each of these plates, A. B. Fig. 3, is in metallic connection with the induction coil so as to be its terminals. When thus connected, and one makes and breaks connection in the primary circuit, a click may be heard by one holding the receiver near to the ear. If a Helmholtz interrupter be employed to make and break the primary circuit the pitch of the fork can easily be heard, and with a *Reiss transmitter* or other suitable one in the same place any kind of a sound will be reproduced.

The explanation of this is easily understood from the foregoing description of the conditions present. The electro-motive force generated by induction in the coil changes the two terminals in the receiver, one positively the other negatively; they therefore attract each other.

One of them is free to move, while the other is rigid. The middle of the freer plate consequently moves slightly toward the other whenever they are electrified, and *in so doing spends the energy of*

the electricity, while its elasticity brings it back to its place. It is not essential, however, that both of these terminal plates should be connected to the induction coil, for if only one is connected the recurring charges will cause the free plate to vibrate, for a charged body will attract any other body, so if the connection be to the back plate it will attract the front one and make it move, and if the connection be to the front plate it will attract the back plate and approach it. The effect will be increased by putting the finger upon the terminal that is free; not because it *makes a ground*, as it is termed in electrical science, or completes an electrical circuit, for, if the individual listening be as perfectly insulated as glass or hard rubber can make him, the sound is as loud as if he stood on the ground; but the individual becomes electrified by induction, it is the same as enlarging the terminal would be. Consequently receivers are made having only one wire terminal (see Fig. 9), the other plate being connected by a conductor to a metallic ring upon the knob, and this receiver is as efficient as the other.

Electricians will recognize in this structure what is technically known as the *air condenser*, and the mutual attraction of the two plates has been employed as a means of measuring electric potential. In this case one of the plates is suspended from one arm of a balance, while the other is fixed underneath it at a short distance. The attraction of the plates when they are electrified requires an extra weight to keep them apart, and the weight needed is the measure of the attractive force. But the plates will attract each other when glass or mica or any other non-conducting substance is placed between them in the place of the air; and one might expect that if such an air condenser would give sonorous results other forms of condensers would do so likewise, and this is so. Indeed, whoever has charged a Leyden jar has probably noticed the sounds coming from it when it is nearly saturated. In 1863 Sir William Thomson had his attention directed to the sounds produced by discharge in an air condenser.*

When the two plates of Epinus' condenser are in metallic contact no sounds whatever can be produced by it, but if they are

*See papers on Electro Statics and Magnetism, page 236.

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*See papers on Electro Statics and Magnetism, page 236.

separated by a thin film of air, they will reproduce speech (see Fig. 6, at E). In the first case the electricity passes from one plate to the other without doing work or changing its form; while in the latter its form is changed and work is done, and between the best conductors, such as silver and copper and the perfect non-conductor air, there are all degrees of conductibility, and whenever electricity spends its energy upon an imperfect conductor it results in heating it; that is, in molecular and automic vibrations. Consequently an undulatory current from an ordinary transmitter, when sent through an imperfect conductor, will set up sound vibrations in it which may be appreciated by the ear. Let, then, any poor conductor, like a disk of carbon, a sheet of paper or of gelatine, or such chemical substances as ammonium chloride, be placed between the terminal plates, and an undulatory current sent through them will result in sound, and speech may be reproduced.

Now, the phenomena observed in Geissler's tubes and Crookes' tubes show that the residual gaseous molecules are violently impelled from the electrified terminals, not simply because they are electrified, but because they are heated, for the same phenomena are witnessed when the terminals are heated in other ways; so it is probable that between the plates of the air condenser there is an actual impulsion of the air particles from one to the other, and that the phenomenon of attraction is not isolated from molecular impact. Receivers have been made in which a vacuum could be produced between the plates but no great difference could be observed in their performance; and, when one reflects upon the immense number of molecules left in the best vacuum yet produced, it is not a matter of much surprise.

When a non-conductor, such as air, or vulcanite, or mica, separates the two plates, there is a complete transformation of the electricity at the limiting surfaces, and with small condensers the efficiency depends upon the electro-motive force employed. For low electro-motive forces, such as common batteries of a few cells can give, the effect is almost inappreciable, and for this reason such a receiver as this is quite free from the disturbance known as induction, and which is so troublesome in the magneto telephone, such induced currents being generally of low electro-motive force.

Among the earliest of my experiments, made while developing

this method, was to attach one terminal wire from an induction coil to the outer coating of a Leyden jar, taking the other wire from the coil in one hand, and applying one ear to the knob of the jar Every word spoken at the transmitter was distinctly heard, but the prickly sensation due to the electricity was too disagreeable. Another receiver, not less curious than the Leyden jar, was found in the pair of insulating handles made for the medical application of electricity (Fig. 8). When these were connected to the coil wires, and one held in each hand by the wooden part, while the metallic ends were placed at the ears, any kind of a sound at the transmitter was heard without any difficulty, but of course the same sensation was felt as with the jar. Many forms of condensers have been employed with capacities too small to measure up to two micro-farads, and these in all sorts of relations, charging the plates from batteries, from Holtz machines, charging the line as in cable works, etc., all of which give results that differ only in degree.

THE TRANSMITTER.

As with other systems in common use, there is a transmitter as well as a receiver. One form of the transmitter is shown in Fig. 10, it being attached to the door of a box containing battery and coil. This transmitter is substantially the same as the one invented by Reiss in 1861. His consisted of a cubical box (see Fig. 6) about five inches on a side, having an opening on one side to talk into, and another one on top, across which the diaphragm was fastened. A pin of platinum was glued to the middle of the membrane and connected by a wire to a binding screw. A V-shaped wire with platinum point touched upon the platinum of the membrane, and with its binding screw served to complete a galvanic circuit. This one (see Fig. 10) differs from this of Reiss only in making the chamber smaller, making the connecting wire on top I-shaped, and substituting carbon or other suitable substance for the platinum; but the platinum does very well. It is a matter of some surprise that the old transmitter is still spoken of as a *make and break* circuit, and that it can only transmit pitch, whereas, whether it breaks or not when a sound is made in it depends solely upon the intensity of that sound, just as with the Blake transmitter. If one talks gently to the

original Reiss transmitter it not only does not break, but it transmits speech with all its qualities.

Accompanying the transmitter an induction coil is shown at I, Fig. 6, and as the working of the receiver depends upon electro-motive force and not upon current, it is necessary, if a coil be used to raise the electro-motive force, to have one with many more turns than is needed with the magneto receiver. and the best results have been obtained with a coil having a resistance of four or five thousand ohms, but it is probable that this will be reduced.

On account of the high electro-motive force a better insulation is needed than ordinary telegraph lines give when the induction coil is at the further end of the line, but if it is at the receiving end, and a low electro-motive force is employed in the primary, then ordinary insulation will answer. Again, the electro-motive force being high, inserted resistances do not so markedly decrease the efficiency of the instrument, as in the case with the magneto telephone. For instance, the articulation is perfect and loud enough with a resistance of fifty thousand ohms, a resistance equal to five thousand miles of common telegraph wire, and it may be heard through the resistance of a million ohms, practically an infinite resistance.

If one of the terminals of a receiver be charged in any way the reaction between the two plates will be stronger than it will be without. Let, then, one terminal be attached to a knob of a Holtz machine that is kept charged by rotation. The sounds will be heard much louder, and any other source of electricity with high potential will answer the same purpose. Hence a battery of a large number of cells may be substituted for the Holtz machine, and one of the terminals of the battery may go to the ground, though this is not essential. This arrangement will keep the terminal plate charged to the potential due to the chemical relations and number of cells in the battery. If the battery be placed in the line wire it will keep both ends of the line charged. A Volta's pile may be substituted for the battery in either place, and so may a charged condenser of any capacity, the electrically charged terminals in this system acting in a way analogous to the permanent magnets in the magnetic system.

There are various other ways of employing condensers, and as one would infer from the preceeding descriptions of the phenomena, these

condensers will talk, that is, they will reproduce in sound the varying electrical conditions to which they may be subjected, as will also either a battery or a Volta's pile.

I have often heard them talk, and have made many experiments with such receivers.

Several other diagrams are also added, showing some of the various ways in which the system may be employed.

In perfecting this new telephone Professor Dolbear has given long and constant study to the scientific problems involved, while the mechanical construction has been prosecuted by H. C. Buck, aided by skilled machinists and competent assistants. The above concise description in the inventor's own words will give our readers a clear understanding of the principles that underlie his interesting invention, and it only remains for us to describe in brief the several figures in our front-page engraving.

Fig. 1 shows the telephone in actual use, the transmitter being secured to the wall, the battery and induction coil being placed in a box on the floor, or in a convenient closet. Fig. 2 is a perspective view of the new receiver; Fig. 3 a face view of the same, with a portion of the casing broken away to show the connection of the two binding posts, A B, with the diaphragms, C D, and the adjusting screws by which the distance between the diaphragms is regulated are shown in the sectional view, Fig. 4.

Fig. 5 illustrates the principle of electrical attraction upon which the action of the new receiver is based; the electrostatic charge received by the plate, E, from the induction coil attracts the pith ball suspended in front of the plate.

Fig. 6 shows the two plates, E, of an Epinus condenser, placed near together and connected with the terminals of the secondary wire of the induction coil, I, and used as a telephone receiver.

Fig. 7 shows an induction coil with a separable primary for illustrating the principles of electrical induction.

Fig. 8 illustrates the manner of securing telephonic communication through ordinary medical electrodes.

Fig. 9 illustrates the essential features of the new telephonic system. I being the induction coil whose primary is in circuit the with battery, B, and transmitter, T; the receivers, R, are each connected with a single terminal of the secondary wire of the coil, I.

Fig. 10 shows Professor Dolbear's experimental telephone transmitter. In this instrument the diaphragm, A, is horizontal, and carries a carbon electrode, upon which rests a movable carbon electrode connected by an arm with a delicately pivoted bar supported by the diaphragm cell. The local circuit is from the battery, B, through the carbon electrodes, and through the primary of the induction coil, I.

Fig. 11 shows the exhibit prepared for the Paris Electrical Exhibition, and intended to represent the perfected telephone system. It shows two similar

196
198

instruments, which in practice are placed at opposite ends of the telephone line. T is the transmitter, B the battery, I the induction coil, R the receiver, and G the ground. *b* is a key for cutting out the receiver when it is desired to talk, *d e* are the primary wires, *f* the secondary wire leading to the key, *h* the line connection of the receiver, and *i* is the ground connection of the receiver.

Circuit Court of the United States.

DISTRICT OF MASSACHUSETTS.

IN EQUITY.

No. 1628.

AMERICAN BELL TELEPHONE COMPANY

v.

AMOS E. DOLBEAR ET AL.

AFFIDAVIT OF AMOS E. DOLBEAR.

AMOS E. DOLBEAR, of lawful age, being duly sworn, says,—

I am one of the defendants.

I am professor of physics at Tufts College, and have been since 1874. I have devoted my entire time to the study and teaching of physics since 1868, and for the past twenty-five years have been a constant student of electric and acoustic phenomena.

I believe I fully understand the various methods of and apparatus electrically reproducing sound now known, and the physical laws underlying them.

I adopt the exposition given by Professor Cross of the theory of sound in his affidavit, remarking, however, that Helmholz' theory was demonstrated and published as early as 1859, and was widely known both in Europe and in this country before 1860.

Electricity is a physical condition of matter which is capable of manifesting itself in two ways: *first* by attracting neighboring bodies; *secondly*, by distributing itself with great velocity throughout some substance. In the former case it is said to be electrical *attraction;* in the latter case it is said to be a *current* of electricity. In the former case it is necessarily at rest, and its energy is potential energy, and it is called static electricity; in the latter case it is

necessarily in motion, and its energy is kinetic energy, and it is called dynamic electricity.

That a current of electricity traversing the coil of an electro-magnet would induce in the coil magnetism, the polarity of which varied with the direction of the current, and the strength of which varied with the strength of the current, and that a metallic plate or diaphragm set up within the magnetic field of such a coil would give out sounds by reason of its vibrations towards the magnet in obedience to magnetic attraction, and away from it by its own resiliency, and that such vibrations would produce in the adjacent air sounds corresponding in pitch with the rate of variations in the strength of the current traversing the coil of the electro-magnet, was well known before the date of Professor Bell's patent of 1876, in suit in this case, or, so far as I am informed, of his invention described in that patent. Reis (to speak only of such results produced and published by him as I suppose to be not controverted) had done this, employing a transmitting diaphragm which was set in vibration by the impact of the air-waves produced by the utterance of speech against it, and whose vibrations caused variations of strength of current in an electric circuit which included an electro-magnet at a receiving station, such variations of strength of current corresponding in rate to the said air vibrations, and in turn inducing in the receiving electro-magnet corresponding magnetic vibrations, which again, by the vibrations of a metallic plate in the magnetic field, were converted into air-waves similar in rate to those produced at the transmitting station, thus producing sounds of similar pitch to those uttered at the transmitting station. This instrument is said to have been incapable of transmitting speech, because as is alleged, the electric circuit was not constantly under the control of the moving part of the transmitter, but was at times broken by the movement of the transmitting diaphragm. And it is also alleged that the Reis receiver was not adapted to reproduce from the conducting circuit, even if his transmitter has been adapted to produce upon it, all the variations involved in the telegraphic transmission of speech.

I will assume that this is a correct summary of the results accomplished by Reis. So assuming, it appears that by means of the

vibration of a diaphragm under the influence of air-waves produced by speaking, he produced certain vibrations of current in an electrical circuit, which vibrations of current were converted into corresponding vibrations of magnetism, which produced corresponding vibrations of a plate, whose action upon the air produced sounds similar in pitch to those uttered at the transmitting station.

The method here employed of using electricity for telegraphing sound, namely, by producing variations in a *current* of electricity traversing the coils of an electro-magnet in which corresponding magnetic variations were induced, was the only way known at the date of Bell's patent in which electricity could be made to cause mass vibrations of a plate, and so give out a definite tone.

The Bell telephone described and represented in the Bell patent of 1876 is based upon and makes use of this same property of electricity, by which a *current* of it can be converted into *magnetism*, which may then serve as the agent to cause the necessary vibrations of the diaphragm sensitive to magnetic attraction at the receiving station.

I feel sure that Mr. Bell did not know, nor did any one know, that electricity not converted iuto magnetism, but static and acting by its potential energy, could be used to produce such vibrations of a diaphragm, or indeed any continuous vibration at all.

This is a discovery of my own, made since Bell's patent, and upon which my method of telegraphing speech is based.

Professor Cross, in his affidavit filed in this case, says that it was well known before the date of Bell's patent that "the attractive "power of one plate on another varied with the electrical condition "of the first. This is true.

Next he says, "It was also well known before the date of said "patent that *by this means* the electrical variations in the secondary "circuit of an induction coil could be made to cause such *vibratory* "*motion in a plate* as to thereby produce a sound whose pitch cor- "responds to the rate of the electrical variations." If this means mass vibration of a plate or diaphragm or any such thing, produced in it by means of electric variations in the terminal plate, or, in other words, by means of variations in the electric potential of such a

plate, I can only say, in the absence of any specification by Prof. Cross of the patent or publication or other reference he has in mind, that I know of no such thing existing before Bell's patent, or before my own discovery, and I believe that he is in error.

He goes on to say, "And this device for converting electric "variations into sound-waves was well known as an equivalent and "substitute for the motion given to a vibrating armature by means "of the varying attractions of an electro-magnet through whose "coils the same varying current should be passed." In this I have no doubt that he is in error. I have had occasion to exhibit my telephone to a great many skilled electricians, and without exception they have expressed their astonishment at hearing that variations of the electric potential of a terminal plate could practically produce any sound vibrations of an opposed diaphragm comparable to those produced by the varying attractions of an electro-magnet.

I reproduce speech in my telephone by means of variations of the electric potential of a charged condenser. Up to the time of my invention, what was known as to the production of sound by condensers or opposed plates was very meagre. It had been observed that a condenser, when discharged suddenly, gave out a short sound, and a Reis transmitter had been used in the primary circuit of an induction coil with a condenser in the secondary circuit to reproduce pitch by the sudden discharges of the condenser rapidly following one another, being the experiment referred to in Mr. Pope's affidavit in this case. This was the most advanced stage of knowledge, so far as I know or have any reason to believe, until after 1876. The sound obtained from the discharges of the condenser as just mentioned was not obtained by any vibration of either plate of the condenser produced by the change of potential of the plates, but was obtained by the disruptive discharges of electricity from one plate to the other. Such a mode of producing sound cannot possibly be extended to the production of anything but pitch.

The discovery upon which my method of telegraphing speech is based was made by me while experimenting with a telephone based upon the principle that a current of electricity will decompose a compound chemical substance; in these experiments I put the sub-

stance to be decomposed between two plates, the terminals of an induction coil of about 2000 ohms' resistance; and during these experiments I was surprised at hearing speech on one occasion where air only was between the plates, and when it was clear to me that there could have been no discharge from plate to plate. This led me to experiment further, and these experiments resulted in my present method and apparatus.

I believe it to be broadly true that before my discovery it was unknown that *variations* in the potential of a terminal, as distinguished from sudden discharge, could be used for my purpose, and I believe that I was the first to use them for any purpose. For example, I have discovered that the potential of a plate will give it, or a plate opposed to it, motions exactly corresponding to the changes in potential, whether the potential be increased during all of a certain period of time, whether with regular or with varying rates, or decreased during a certain period with regular or with varying rates, or both increased and decreased with rates regular or constantly varying. The fact that a condenser will give out a sound when suddenly charged or discharged, has no relation to the fact that sound-waves can be produced in air by varying the potential of a plate opposed to some other body. It is not possible in the nature of things to produce speech by charging and discharging a condenser, no matter how it is done, for the discharges are practically instantaneous, and the sound-waves of speech require definite times.

There are necessarily some resemblances between Mr. Bell's method and mine, because both are methods of telegraphing speech.

He throws upon an electric circuit variations like those which the utterance of a sound has produced in the air, and the same is true of my telephone. This is a physical necessity of the use of electricity at all for the purpose of transmitting speech. There must be electrical variations of some sort on the wire, and the electrical variations (whatever they are) must correspond with those which the voice has produced in the air. Unless these things are done, the use of electricity for the purpose of transmitting speech is physically impossible. I assume, then, in comparing Mr. Bell's method of tele-

graphing speech with my own, that some identity beyond this must be found, if they are to be regarded the same in principle.

It is true that by Mr. Bell's method the air-waves produced in speaking are caused to vibrate an instrument which holds the electrical circuit under its control constantly, so that whatever movement of the diaphram at any instant may be made, will be converted into a corresponding electrical variation on the line wire. And I do the same. But I consider that the two methods are nevertheless substantially different, because the electrical variations in the two cases are wholly different in character, those used by me being static or potential variations, which were not known or supposed to be available as an agent for inducing vibrations of a diaphragm, and which, when used for that purpose, do so in an essentially and radically different manner from that in which the electrical variations act which are employed by Mr. Bell.

He converts his electrical variations into magnetic variations, and so vibrates the receiving diaphragm by a property of both which was well known ; and he is able to effect this conversion because he uses the dynamic or kinetic energy of electricity traversing a coil ; in other words, his electrical variations are variations in an electrical current.

I do not convert my static electric variations into magnetic variations, because they are static and not dynamic. I use them directly and without change, to effect the vibration of the receiving diaphragm. The possibility of so using static electrical variations, or variations of electrical potential, was not known until I discovered it.

The two methods of telegraphing speech are, I truly believe, essentially and radically different, based upon different electrical laws; based, in my case, upon an original discovery of a capacity or power of electricity not previously known or believed to exist, *i. e.*, the power of electricity acting through its static or potential form to attract, according to variations of its electrical potential, a body electrified to a different potential, and to thus produce sonorous vibrations.

When speech is transferred from one place to another electrically,

whether by a known method or one not yet imagined, it is perfectly certain that the sound at the transmitting station must so act as to cause the electric energy upon the line to vary in its strength with the varying phases of the sound to be reproduced, because the problem is to reproduce one form of energy by converting it into a second form of energy; that is, air vibrations into electric vibrations; and it is a truism that the electric vibrations must conform to the air vibrations which produce them, if the electric vibrations are to be used to produce air vibrations like the first. Let me speak of it, for this purpose, as form of energy A. Now A is not electricity, and if electricity is to supplant A, A either must be transformed into electricity or be applied in some way so as to modify a current of electricity or an electrified body, so that any phase of A shall have its counterpart in electricity, for the latter is the agent to do the work at the receiving end. So much is inevitable, and due, not to invention, but to the physical laws involved. The methods for doing this are proper subjects for invention.

Now, electricity is a form of energy also; call it E. If form of energy A′ is to be like A, and is to be produced by E going from A to A′, it is a physical necessity that E must conform in all particulars to A, so that every phase of A shall have a corresponding phase in E; for nothing can be produced at A′ except by the various phases of E.

That these conditions which are employed in the telephone involve what is known as the conservation of energy, and are mathematical in their nature, is allowed and must be allowed by any one understanding them.

I will now compare my method and apparatus more in detail with those described in the Bell patent.

As to the method: Considering figs. 5, 6 and 7 in the light of the description of Bell's method, I have no doubt that Bell's method of reproducing sounds consists in (1) converting the energy of sound-waves into magnetic variations; (2) converting these magnetic variations into electric variations; (3) reconverting these electric variations into magnetic variations; and (4) reconverting these last magnetic variations into new sound-waves; each one of these trans-

formations being an example of the conversion of one form of energy into another form, according to the well known laws of the conservation of energy and correlation of forces.

The apparatus for employing this method consists of (1) a device which is operated by the energy of the sound-waves; (2) a magnetic system, the energy of which is varied by the operation of this device; (3) a conductor circuit in which electric energy is set up by the variations of the magnetic energy of the first magnetic system; (4) a second magnetic system, the magnetic energy of which is varied by the variation of the electric energy in the conductor circuit; and (5) a device which is operated by the variations of magnetic energy in the second magnetic system to reproduce sound-waves. My method differs from Bell's (if the above be taken as Bell's) in these respects.

I use the energy of the sound-waves to control the electricity in a circuit, instead of converting that energy into magnetic variations, as Bell does; and this difference is very important practically, for the reason that all the magnetic energy Bell can get, can never exceed; and practically must fall much short of, the energy of the sound-waves, which is itself necessarily weak; while in this part of my method (which is not mine, but borrowed from Reis) the electric energy has no relation to the energy of the sound-waves, but the electric energy used is very many times greater than the energy of the sound-waves; and this because the energy of the sound-waves is not converted into another form of energy, as in Bell's method, but is employed solely to regulate the supply of electric energy; the difference being much the same as between turning a wheel by hand, thereby converting muscular power into motion, and moving water-gates by hand, thereby giving motion to the wheel. This electric energy I convert into magnetic variations, but it is the fact that any magnetic variations which can be practically obtained by converting the energy of sound-waves is wholly inoperative in my system; for my receiver will not work practically, if at all, with a magneto-transmitter. But even assuming that I do convert sound-waves into magnetic variations, and therefore must be held to employ the first step in Bell's method, how is it as to the second

step? It is true, in some sense, that I convert these magnetic variations into electric variations; but it is the fact that the electric variations utilized in my method are radically different from those used in Bell's method. In Bell's method variations in current strength are essential, while in my method the electric variations are static. I use magnetic variations solely to obtain great variations in potential or charge, not to obtain variations in current strength. In Bell's method, the greater the variations in current strength, the better the result; in my method current variations are not utilized.

In Bell's method, Ohm's law,—*i. e.*, electro-motive force divided by resistance, equals current strength, — is applicable to the electric variations; while that law has no application whatever to the electric variations used in my method.

To make this clearer, suppose a soft iron core surrounded by a primary and secondary coil. So long as the current strength of the primary circuit is constant, the magnetic strength of the soft-iron core will be constant; but upon any variation of the current strength in the primary circuit, the magnetic strength of the soft-iron core will vary proportionately; and instantaneously with each and every variation of the magnetic strength of the core, the secondary coil will become electrified, one end being positive, the other negative; that is, the ends will be at different potentials; and their potentials will vary instantaneously, at each and every variation of the current strength in the primary coil, and there will be no current, but simply electric tension or electric pressure in the secondary coil. The energy is potential only, not kinetic; while in all currents of electricity the energy is kinetic and not potential. The two names for these electric conditions are static and dynamic.

The ends of the secondary coil, when the coil is electrified, will attract each other, and the force of that attraction will vary directly as the electric tension or potential varies, other things being equal.

Enlarging the surface of either one of the ends will very greatly increase its attractive force, the increase in force being directly as the increase in surface, supposing the tension to be the same until the terminal receives its maximum charge.

It is this quality of electric variations, viz., variations in electric

tension or electric pressure or charge, into which the energy of the magnetic variations is converted in my method, while in Bell's method the energy of the magnetic variations is converted into vibratory currents. The difference between us in this respect is almost precisely the same as the difference between the energy of a varying current of water and the energy of a varying head of water. It is impossible to apply the electric energy active in Bell's method to work my receiver, and impossible to apply the electric energy active in my method to work Bell's receiver; and this is to my mind emphasizes the difference I am now dealing with, which is, that although it is true in a sense that we both convert the energy of magnetic variations into electric energy, yet it is clear to all skilled in this art that the electric energy into which I convert the energy of the magnetic variations is a wholly different electric energy from that into which Bell converts the energy of magnetic variations; at least as different as the kinetic energy of a given number of cubic feet of water flowing from one point to a lower one in a given time is different from the potential energy of a column of water with no outlet, and so different that all will agree that it is physically impossible to utilize the potential energy of electric variations in Bell's method, and equally impossible to utilize the kinetic energy of electric variations in my method.

The above considerations of the second step of Bell's method applies in a measure to the third step which in Bell's method consists in converting the energy of electric variations into magnetic variations.

This I omit wholly. I convert the potential energy of my electric variations directly into motion, while Bell converts the kinetic energy of his electric variations, first into magnetic energy, and that into motion. This part of my method, viz., the direct conversion of the potential energy of electric variations into sound-waves of all characters, is, so far as I know or have any reason to believe, a new discovery. I discovered it, as I have stated, almost by accident, and while searching for a wholly different matter; and up to that time the knowledge on the question of the production of sound by condensers, or opposed plates not in contact, was very meagre, as I

have before stated, and what was known tended strongly to show that such plates were not at all adapted to reproduce anything but pitch.

The following facts were all well known before 1876; viz., that an electrified body would attract all other bodies, except such as were electrified with like electricity; that two electrified bodies would repel each the other if both positively or both negatively electrified, and would attract each the other if one were positive and the other negative; but I am not aware of any methods or apparatus utilizing these facts before my discovery and invention, except only electrometers and like instruments in which two plates or leaves are charged with like electricity and therefore repel one another, or in which a suspended body, as a pith-ball, is caused to move by being electrified. I have no doubt that I was the first to discover that variations of charge (which is precisely the same thing as variations of potential, or of electric pressure, or of electric tension, and a wholly different thing from variations of current) could be used to produce any desired effect.

Taking the above view of Bell's method, his apparatus is, in essence, two magnets, two armatures, two coils and a conductor circuit of which both coils form a part. My apparatus, as most commonly used, consists of a primary circuit, containing a transmitter, a battery and a primary coil, a magnet within the primary coil, and also within a secondary coil, with the terminals of the secondary coil enlarged and opposed. It is obvious, therefore, that my apparatus lacks the magnet and its coil and armature which are in Bell's receiver. It is also the fact that the construction and operation of the coil and magnet which I use differ widely from the transmitting coil and magnet of Bell's apparatus, because my secondary coil must be of very high resistance, say upwards of 2000 ohms (and better 5000 than 2000) to produce a sufficiently high charge in the secondary coil, while the transmitting coil of Bell's apparatus is in practice only a slight resistance, say about 150 ohms and inoperative with my receiver, although especially adapted for Bell's receiver, because Bell's receiver works to the best advantage when the transmitting coil is such as to produce that current best adapted for the coil and

core of the receiver; anything in excess is not only wasted, but hurtful. The resistance of the transmitting coil is an example of internal resistance, while that of the receiving coil is external resistance, and it is perfectly well known that for the maximum effect the internal and external resistance should be equal.

This, to my mind, also throws much light upon the absolute difference between my method and apparatus and that of Bell; for in my case the internal resistance should be about 5000 ohms, and may well be very much greater; but the external resistance is many millions of ohms, practically infinite; and if the internal resistance in my case should equal or exceed the external — which is practically impossible — my apparatus would not work, because sparks would pass rapidly between the plates, and destroy its action as a receiver.

Bell's method and apparatus may be considered as follows: Bell's method may consist in (1) regulating a continuous voltaic current by the energy of the air waves; (2) converting the energy of this regulated current into magnetic variations, and so on as before. His apparatus, in this point of view, will consist of a primary circuit containing a transmitter, a battery, and a primary coil substituted for the transmitting armature of his apparatus as at first considered.

Taking this view of Bell's method and apparatus, my method and apparatus is the same in substance so far as concerns the primary circuit, with a transmitter, battery, and primary coil in it, as the like parts of the assumed Bell method and apparatus. But all that I have said as to the vastly different electric variations in the secondary coil, and the wholly different method of utilizing them, remains, of course, equally applicable here.

Lastly, Bell's method and apparatus may be considered as follows: Bell's method may consist in (1) regulating a continuous voltaic current by the energy of the air wave: (2) converting the energy of this regulated current into magnetic variations; and (3) converting these magnetic variations into sound waves, or precisely what Reis tried to do. His apparatus, in this view, will consist of a line

conductor circuit, containing a transmitter, a battery and a coil, a magnet in this coil, and an armature controlled by it. In this view, I have a conductor circuit, a battery and a coil, with a magnet in the coil, but lack the armature, and also lack any equivalent or known substitute for the armature. And my method, while the same as the assumed Bell method, so far as concerns regulating a voltaic current by the energy of the air-waves, and converting the energy of this regulated current into magnetic variations, is yet wholly different in all other respects from the assumed Bell method; for magnetic variations are wholly inoperative upon my receiver until they are converted into the electro-static variations which I have fully described. Moreover, the electric variations utilized by me and which I have no doubt are wholly new with me, are widely different from any electric variations in the assumed Bell method and apparatus, as I have above fully explained.

The practical advantages of my method and apparatus over Bell's, whichever one of the three views above mentioned may be taken of Bell's are: *First.* The very high potential or electric tension which is the essential and most striking feature of my electric variations practically remedies all the very serious ill effects arising in all other telephones from induced currents and earth currents; and the reason of this is that the tension of such currents is very trifling compared to the electric tension necessary to operate my receiver; although the strength of such currents is amply sufficient to seriously interfere with the operation of any other receiver known to me, even on short lines, and is fatal in lines of any great length.

Secondly. On account of the very high tension of my electric variations resistance in the line is of no practical importance; while it is of very great practical importance in all telephones which operate under Ohm's law.

My discovery that electric variations of extremely high and varying tension were adapted to produce vibrations of all qualities, enables speech and all other sounds to be readily transmitted over very much greater distances than with any other telephone, and under circumstances (such as earth currents, proximity of other wires, &c., &c.) where any other telephone would be inoperative.

These two difficulties, viz., restricted length of line and disturbances from earth currents and induction, were ascertained by experience several years ago, and are problems a solution of which is of the greatest importance.

There are other practical advantages of my method and apparatus over Bell's, but second in importance to the very great advantages above mentioned. These are, that very many of my receivers can be used on one wire, which is practically impossible with Bell's; there are no fine wire helices in my receivers which are in constant danger of destruction in Bell's from atmospheric and electric-light currents. The simplicity and durability of my receiver is also advantage.

To sum up: Assuming that Bell's method includes all methods of reproducing speech in which electricity is the agent, then it certainly includes my method. Assuming that it includes all methods of reproducing speech in which the phases of the electricity used correspond with the phases of the sound-waves, it also includes my method, and must necessarily include all methods in which electricity is used; for it is physically impossible for electricity to do the aequired duty unless it so corresponds with the sound-waves generating or controlling it. Assuming that it includes all methods in which the electricity generated or controlled by the sound waves is utilized by any means known at the date of Bell's patent for utilizing it, *e. g.*, by its magnetic, chemical or heat effects, then it does not include my method, for the electric variations utilized in my method are static, not dynamic, and cannot produce any of the effects above named, and the effects of rapid variations of potential had not been discovered until I discovered them.

Assuming that Bell discovered that a rapidly varying current of electricity traversing a helix within which a magnet would cause the armature of that magnet to reproduce the air-waves by which the current was caused to vary, it is yet true that he did not discover that rapidly varying the potential of two opposed plates would reproduce the sound by which such potential was caused to vary; and while it is true that it was known to students before the date of his patent that the potential of the ends of an induction coil must vary with every variation in the current which traversed the primary

circuit, yet no practical use had ever been made of this knowledge except to charge the terminals of the coil sufficiently to produce a discharge between them; and there was no reason to believe, so far as I know, before my discovery of the fact, that rapid variations of charge could be used to produce sound-waves.

A. EMERSON DOLBEAR.

UNITED STATES OF AMERICA,

DISTRICT OF MASSACHUSETTS, } ss.
COUNTY OF SUFFOLK, }

Subscribed and sworn to at Boston in said district this sixth day of January A. D. 1881.

Before me,

[SEAL] J. HENRY TAYLOR,
Notary Public.

AFFIDAVIT OF FRANK L. POPE.

FRANK L. POPE, of lawful age, being duly sworn, says,—

My name is Frank L. Pope; age forty-one; I reside in Elizabeth, N. J., and am a solicitor of patents. I have been a working electrician and electrical engineer for more than twenty years, and am familiar with the construction and operation of nearly if not quite all the different kinds of telegraphic and electrical apparatus in practical use. From 1875 to 1880 I was employed by the Western Union and Gold & Stock Telegraph Companies of New York city as an expert, my particular business being to examine and report on the novelty, utility and patentability of the various inventions which were constantly brought before the officers of these companies for adoption; and also to advise in a general way upon all matters of that character. I have been acquainted with the speaking telephone since the summer of 1877, and was familiar with descriptions of the same which were published prior to that time. In August, 1877, I made a thorough examination of the whole subject of harmonic telegraphy up to that date, including the speaking telephone, and from that time until the present have endeavored to keep myself informed

as completely as possible of everything that has taken place in the way of developments and improvements of the original inventions.

I have carefully read the patent of Mr. Alexander Graham Bell, viz, No. 174,465, dated March 7, 1876, and believe that I understand the invention therein described. I understand the apparatus known as the Bell speaking telephone, and the method by which the same is operated, to constitute the subject matter of the fifth claim of said patent, which claim is as follows:

"The method of and apparatus for transmitting vocal or other "sounds telegraphically, as herein described, by causing electrical "undulations similar in form to the vibrations of air accompany-"ing the said vocal or other sounds substantially as described."

The *method* of transmitting vocal or other sounds over a telegraph line which is described in the specification of the patent, consists in causing the vibrations of the particles of air which necessarily accompany the production of a sound, to impart a mechanical movement of like character to a body so constructed as to be capable of being thrown into corresponding vibrations. By the movements of this body an electric current of varying strength, which the specification calls an undulatory current, is produced at the transmitting station in a continuous circuit of electrical conductors, which includes the coil of an electro-magnet at the receiving station. This varying electric current induces magnetism in the core of the said electro-magnet, the intensity of which varies in proportion to the strength of the inducing current. The armature of this electro-magnet is attached to, or consists of, a resonant plate or diaphragm, which, when subjected to the varying attraction of the magnetized core, is thereby thrown into vibrations, which are mechanically communicated to and taken up by the air-particles in its vicinity, thus producing at the receiving station vibrations of the resonant plate like those of the vibrating portion of the transmitter, and these vibrations being communicated to the air particles reproduce (although with diminished intensity) the original sound first produced at the transmitting station. The method described therefore comprises the following series of successive steps or operations:—

1. The communication of physical motion from the air to the

transmitting diaphragm. 2. The production of electrical undulations in the conducting circuit by the motion of the diaphragm. 3. The production of varying degrees of magnetic intensity in the core of an electro-magnet by the action of an undulatory electric current traversing its enveloping coil. 4. The production of physical vibrations in a resonant plate by the varying magnetic attraction to which it is subjected by the said electro magnet. 5. The production of sonorous vibrations in the atmosphere by the physical vibrations of the resonant plate.

The *apparatus* described in the specification by means of which the foregoing methods is to be carried into effect, consists of a body capable of responding to sonorous vibrations in the atmosphere; that is to say, of taking up from the atmosphere the same character of vibration, which body acts inductively to vary the magnetic intensity of an iron core surrounded by a coil of wire, whereby magneto-electric currents are set up in the coil, the duration and force of which are determined by the rapidity and extent of movement of the inducing body in the neighborhood of the core. A continuous circuit of electric conductors extends from the transmitting to the receiving station, and includes the coil of the transmitter as well as the coil of another electro magnet which forms the most essential part of the receiver. The armature upon which this electro-magnet exerts its attraction is affixed to, or is formed by, a resonant plate or diaphragm.

Hence the *apparatus* which is described in the patent consists substantially in a combination of the following elements:

1. A vibrating armature or inductor capable of responding to sound vibrations.

2. An iron core surrounded by a coil of wire, the magnetic intensity of which core is varied by and in accordance with the movements of the inductor or armature.

3. An iron core surrounded by a coil of wire, the magnetic intensity of which core is varied by and in accordance with the strength of the electric current passing through said coil surrounding the core.

4. A continuous electric conductor or series of conductors forming

a circuit which unites the transmitting and receiving stations, and which includes both the coils hereinbefore mentioned, and by means of which the currents induced by one core are made to act upon the other.

5. An armature which is capable of responding to all the different degrees of attractive force produced by the varying magnetic intensity in the core of the receiving magnet, and of communicating corresponding physical vibrations to the air.

The specification states that means of producing an undulatory electric current may be employed other than the one specifically described and illustrated, which consists in vibrating an armature or inductor in the vicinity of the pole or poles of a magnet, several known methods of effecting this being particularly named. In practice a means of varying circuit resistance is almost universally used to vary the magnetic energy of the iron core by which the undulatory currents are induced in the line; viz., that of placing an auxiliary, or in technical language a "primary," coil of wire upon the inducing core, through which primary coil a continuous voltaic current is made to pass, the strength of which is varied by means of a variable resistance, the latter being in turn controlled by the vibrations of the diaphragm or body which is set in motion by the air-waves. The variable resistance, the continuous voltaic current and the primary coil, used in this system, together constitute an equivalent for the vibrating inductor used in the system shown in figures 5 and 7 of the patent, and when substituted therefor produce a similar but much more powerful effect.

The general result which is produced by the method and apparatus described in the patent, is the production at the reciving end of a sound similar to but of less intensity than, the original sound at the transmitting end by which the apparatus is set in action. The receiving diaphragm, however, does not reproduce all the motions of the transmitting apparatus with absolute fidelity. In the conversion of magnetism into electricity, and electricity again into magnetism, a certain change in the form of the vibrations takes place which is due to what is termed the magnetic inertia of the iron core. The mass of iron requires a certain definite length of time

either to receive or to part with its magnetism, and as some of the variations in the strength of the current take place with great rapidity, the full magnetic effect due to the particular strength of current at any given time is not always attained, and hence a strict proportionality between the more and less rapid series of vibrations is not always preserved. From this cause doubtless arises the observed fact that certain sounds and particular words of which those sounds form essential elements are understood with difficulty.

I am acquainted with the speaking telephone apparatus invented by Professor Dolbear; have frequently examined the same, and am familiar with its construction, principle and mode of operation. This apparatus is similar to that described in the affidavit of Edward Davis in behalf of the complainants in this motion, and illustrated in the drawings and diagrams accompanying said affidavit, subject, however, to the following reservation; the description given by him of the circuits, so far as it involves the suggestion, either expressly or by implification, of the passage of an electric current through the receiver to earth or to line, is erroneous, as the diagrams show, and I have satisfied myself by actual examination and experiment that such passage of any electric current is precluded by the theory of Professor Dolbear's method and the construction of his apparatus.

The method of transmitting vocal or other sounds over a telegraph line which is employed by Dolbear, resembles that described in the patent of Bell, in so far as the process of producing variations in the magnetic condition of the iron core of the inducing magnet at the transmitting station is concerned. That is to say, these variations of magnetic energy are controlled by and are correlative with the vibrations of air-particles which are there taken up by the diaphragm or other body. But here the resemblance ends. The process of transferring this action by means of electricity to the reciving station. and of causing at that point the vibration of a resonant plate whereby the sounds are reproduced, is radically different.

Bell's transmitter sets up a varying electric *current* in a continuous circuit of conductors, while Dolbear's transmitter sets up a varying electric *potential* in a linear conductor which does not form a circuit

at all. The varying current in the circuit, according to Bell's method, traverses the coil of an electro-magnet at the receiving station, is converted into magnetism, and again converted from magnetism into mechanical motion, which produces sound. The varying potential in the linear conductor, according to Dolbear's method, gives rise to a corresponding electrical attraction between a part of such linear conductor and an adjacent surface, electrified to different potentials, which electrical attraction directly produces mechanical motion, which in its turn produces sound.

The two methods, in short, avail themselves of two wholly distinct properties of electricity, or two wholly distinct electric energies, namely, the so-called *dynamic electricity* employed in Bell's system, and *static electricity* employed in Dolbear's system. These energies differ, *first*, in their *intrinsic natures*, and *secondly*, in the *effects* they are capable of producing. As regards their natures, the essence of the dynamic electricity is its *motion*, and the essence of the static electricity is its *rest*. Hence their respective names. As regards their effects, each produces a manifestation of energy wholly different from that produced by the other. Dynamic electricity, by virtue of its motion, produces magnetism. Static electricity, by virtue of its lack of motion, produces electrical attraction. These effects, as widely different as the causes which produce them, are respectively used by the two systems. A uniform and continuous *magnetic* attraction can only be produced from the conversion of electric energy by means of a continuous electric current traversing an uninterrupted circuit. If this circuit be interrupted, the magnetic attraction ceases. On the other hand, a uniform and continuous *electric* attraction can only be produced from the conversion of electric energy by means of a continuous difference of potential, which is maintained by a continuous interruption of the conductor. If the circuit be closed, the difference of potential is no longer maintained and the electrical attraction ceases. The property of electricity whereby it exerts a direct attractive force is said to have been discovered by Thales about 600 B C., while the property whereby it is enabled to exert an attractive force through the intervention of

magnetism was first observed by Romagnesi about the year 1805, and afterwards by Oersted in 1819.

The substantial difference, therefore, between the two methods, I find to be this; Bell makes use of variations in the strength of an electric current traversing a continuous circuit to produce magnetic variations, which by their varying attractions produce mechanical vibrations, which in turn produce sound; while Dolbear makes use of variations of electrical potential in a linear conductor, which variation directly causing varying attractions, and these produce mechanical vibration, which in turn produce sound; or to state it more briefly, in the one case there is an indirect conversion of one form of electric energy into mechanical motion through the intervention of magnetism, and in the other case the direct conversion of another form of electric energy into mechanical motion without the intervention of magnetism or any other form of energy. Hence one essential step of the method set forth in the patent is altogether omitted.

The apparatus of Dolbear consists of an inducing magnet at the transmitting station surrounded by a coil of wire which is continuous with the linear conductor. The core of this magnet is provided with an auxiliary coil, a local battery producing a constant voltaic current, a varying resistance, and a diaphragm or other body to respond to the movement of the air-particles, which diaphragm through the immediate action of the parts just mentioned acts to vary the degree of magnetic energy in the inducing core. Thus far the apparatus of Dolbear is substantially the same as the apparatus which is employed in the telephone in general use.

The apparatus at the receiving station, however, is radically different from that of Bell in its construction, principle and mode of operation. Instead of a continuous conductor passing around an electro-magnet and forming a closed circuit, there is a linear conductor which begins with the induction coil and terminates at the receiving station in an insulated metallic plate, forming an enlarge ment or expansion at the end of the conductor. Facing this plate, but separated therefrom by a non-conducting air space, is another insulated metallic plate, so mounted as to be capable of responding

to the varying electrical attractions of the first plate, and thereby producing sounds. The resonant plate need not be connected with the earth nor with any return conductor, because no use is made of any electric current traversing a circuit. This is a new way of using electricity as a means of transmitting sound.

It was well known prior to the date of Bell's patent that the direct attractive force exerted by one body upon another is in proportion to the difference in electric potential existing between them. It had also been observed that when thin sheets of metal are superposed and separated from each other by an intervening sheet of paper, and the plates thus arranged are respectively placed in connection with the opposite terminals of a coil surrounding an inducing magnet, each interruption of the circuit of a primary coil surrounding the same magnet will produce an instantaneous change of potential in the terminal plates sufficient to cause a disruptive discharge from one plate to the other through the intervening sheet of paper. This discharge is accompanied by a spark and by a peculiar sharp crack or snap. When this discharge occurs regularly and with sufficient frequency the succession of cracks or snaps thus produced assumes a rhythmical character, and becomes a simple musical tone, the pitch of which depends upon the rapidity with which the separate discharges occur. A somewhat analogous phenomenon was noticed by Sir William Thompson in the case of the sudden charge or discharge of the well-known Epinus condenser. He observed that when the condenser was charged from a reservoir of electricity (the particular form employed by him being a submarine telegraph cable charged to a high potential and constituting a Leyden jar of enormous capacity) a sound was heard so closely resembling the snap of a disruptive discharge that his ear could not distinguish between them. He noticed tbe same sound also when the condenser was discharged.

There was nothing whatever in the character or nature of the sounds produced by Sir William Thompson in the Epinus condenser, or that accompanying the disruptive discharge in the experiment where the alternate sheets of metal and paper were employed, or in the method by which the sound in either case was produced, that

could in any way suggest the utilization of such a sound so produced for the intelligible reproduction of human speech. The sole result of the repetition of the sound in either case would be merely a tone which could be varied in pitch, but whose character or quality would always remain that of the snap or crack, more or less frequently repeated. Certainly in the operation of the Dolbear apparatus no such sound is audible, and to just the extent that it did occur it would impair the operation of the instrument, by drowning or confusing the other sounds by which the speech is made audible,

Prof. Cross, in his affidavit filed on this motion, says that it was well known before the date of the Bell paaent that by means of the attractive power of one plate on another, varying with the electrical condition of the first, the electrical variations in the secondary circuit of an induction coil could be made to cause such vibratory motion in a plate as thereby to produce a sound whose pitch corresponded to the rate of the electrical vibrations. I think he is mistaken. I know of no such thing before the date of Bell's patent.

So far as my knowledge goes, it was not known prior to the discovery of Dolbear that the varying attraction of an electrified body would cause a plate, capable of mass vibration and having a different potential, to vibrate at all by virtue of that difference of potential, and still less that the loudness, pitch and quality of such sounds, upon which their capacity for reproducing articulate speech depends, cauld be made to vary in accordance with the varying potential of the attracting surface; and it is upon this physical property of an electrified body, which was originally discovered by him, that the method of Dolbear is founded. All that was before known in relation to the production of sounds through the agency of differences in potential between adjacent plates, tended to show that it was impossible to produce sounds differing in any other respect than pitch or rapidity of succession, while their loudness and quality remained unchanged.

I do not find this method or process described, indicated or suggested in any manner in the specification of Mr. Bell's patent.

It is a method or process of using electricity to produce sound vibrations which was not only not known at the date of the Bell

patent, but which nothing that was known tended, in my judgment, to suggest, but rather to exclude.

Speech cannot be telegraphed at all unless electrical action of some sort is made to take place which corresponds with the mechanical action of sound-waves, and which is capable of producing again a like mechanical action. This is necessarily involved in the use of electricity for this general purpose. But the two methods make use of different sorts of electrical action; one of them, that used by Dolbear, having been originally discovered by him, since Bell's patent, to be capable of such use.

The novel method of Dolbear as practiced by means of the apparatus which I have described produces certain improved results of great utility, which may be summed up as follows: 1. The avoidance of interference arising from foreign currents and electrical pulsations from parallel lines which are transferred to the telephone lines by leakage or inductive action and produce extraneous noises. There can be no leakage from another line which will affect the receiving apparatus of the Dolbear telephone, for the reason that there is no conducting circuit whereby it can pass through the receiving instrument, or otherwise affect it in any way. The differences of potential arising from the inductive action of currents traversing neighboring parallel lines are so small that they are not sufficient to perceptibly affect the receiving apparatus. 2. The correct transmission of articulate speech from the transmitting to the receiving diaphragm is greatly facilitated by the omission of one conversion of energy in which the electro-magnet is employed, viz., that at the receiving station, from which arises the fact that the articulation of certain sounds and of words including such sounds, is more full, clear and distinct 3. The parts of the electro-magnetic receiver which are subject to injury from atmospheric electricity or lightning are entirely dispensed with. 4. The receiving apparatus is simple and cheap in its construction.

It is therefore my opinion that neither the combination of apparatus employed by the defendant for the transmission of vocal or other sounds, or the method, means or process by which said apparatus is operated, is the equivalent of that described in the patent of

Bell, inasmuch as one essential element of his combination of apparatus, and one essential step of his process, is omitted, and nothing is substituted therefor which was known as equivalent at the date of filing the application upon which the patent of Mr. Bell was issued.

My attention has been called to the statement in Prof. Cross' affidavit, that "both the instruments [Bell's and Dolbear's] form "parts of an apparatus which as a whole, transmits speech *by* "*means of* certain peculiar variations of electrical currents." If this means that Dolbear uses a complete electrical circuit *as a part of his transmitter*, in which circuit for the purpose of inducing magnetic changes in the transmitting core, such variations of an electrical current are employed as Bell employs in the circuit in which his receiving core is placed, the statement is correct. But I do not understand that any similarity of method in the two cases results from it.

The *transmitting circuit* employed by Dolbear, and the *vibrating inductor* employed by Bell are corresponding elements in their respective systems of apparatus. As already mentioned, either of these elements may be used in the Bell system to produce undulatory currents, and when so used they are the substantial equivalents of each other. But Dolbear does not use either of them to produce an undulatory current. He uses the transmitting circuit to produce a variation of electric potential, and therefore, though the first element of the apparatus of Dolbear may be identical in appearance with the first element of Bell's, still the first step in Dolbear's process is radically different from the first step in Bell's process; all subsequent steps in the two processes being also radically different as heretofore explained.

Subscribed and sworn to before me this seventh day of January, 1882.

FRANK L. POPE.

WM. C. WITTER, [SEAL].
Notary Public.

AFFIDAVIT OF JOHN TROWBRIDGE.

JOHN TROWBRIDGE, of lawful age, being duly sworn, says,—

I am professor of physics in Harvard College, and have devoted my whole time to the study of mathematics and physics since 1865. For upwards of ten years I have devoted especial attention to electricity.

I understand the Bell method and apparatus for transmitting speech electrically, and also the Dolbear method and apparatus.

The main difference between the two systems is that one utilizes what is called dynamic, the other what is called static electricity. It was well known for many years before 1876 that a current of electricity, which is what is meant by dynamic electricity, flowing through a helix would produce magnetic effects; and the state of knowledge as to this has not been advanced at all since 1870, unless it be by what is called Hall's discovery, which has no relation to this matter. In fact, nearly all practical applications, both scientific and useful, of electricity, before Dolbear's discovery, were of currents of electricity, or dynamic electricity, and the effects were produced by the flowing of a current through a helix to produce magnetic effects, or through an electrolytic compound to produce chemical effects, or through a conductor to produce heat effects, or through animal tissue to produce physiological effects. I do not know any practical application of static electricity, that is, electricity not in motion, before Dolbear's; although I have recently seen a description of an apparatus for separating bodies of different sizes by means of electrification; and in this apparatus static electricity only is ultilized. As to scientific applications, I know of none, except such as are involved in electro-static measurements.

Dolbear's system is based upon his discovery that variations of charge can be practically used; while Bell's system is based upon the well-known laws as to the production of magnetic effects by currents of electricity. One very practical difference between the two systems, viz., that Dolbear's is not injured by extraneous dynamic currents, which are always injurious to, and frequently wholly pre- [illegible] the operation of Bell's, depends wholly upon the fact that Dol-

bear's receiver is not affected by currents, but only by charge; while Bell's is affected only by currents.

In both the method of Bell and that of Dolbear electrical variations, corresponding in form with the air vibration produced by the utterance of speech, are set up in the line wire. Unless this is done, it is physically impossible that speech should be transmitted by electricity. Apart from this similarity, I think it clear, for the reasons I have stated, that the two methods of transmitting speech telegraphically are substantially different, based upon different scientific principles.

JOHN TROWBRIDGE.

DISTRICT OF MASSACHUSETTS, } ss. BOSTON, December 28, 1881.
COUNTY OF SUFFOLK, }

Then personally appeared the above-named John Trowbridge and made oath that the foregoing affidavit, by him subscribed, is true.

Before me,

[SEAL] WILLIAM COPELAND,
Notary Public.

AFFIDAVIT OF MOSES G. FARMER.

MOSES G. FARMER, of lawful age, being duly sworn, says,—

My name is Moses G. Farmer; I am sixty-one years old; am temporarily residing in Boston, and am by profession a consulting electrical engineer.

Since 1846 I have been engaged in the scientific study of electricity, and practically familiar with almost if not quite all the modes of its practical application, including the electric telegraph from the time of its invention, electric lighting since 1858, and the electric speaking telephone since 1877. I have experimented with several forms of that instrument, among others those known as the "Bell," the "Blake" and the "Edison," and believe myself to be familiar with the principle and mode of operation of those instruments, and the system or systems of electric telephony in which they are employed.

During the present month of December, 1881, in the city of

Boston, I examined, for the first time, the telephone and the telephonic system, known as those of Dolbear, invented, as I am informed, by Prof. Amos E. Dolbear, and I believe myself to be familiar with its principle and mode of operation.

The "Dolbear telephone," as I saw and tested it, consisted of a transmitter of the class known as variable contact transmitters, its form closely resembling the so-called Reis transmitter as that instrument is shown in contemporary publications, but so constructed as to be less likely to break contact under the impact of voice vibrations and consequently better adapted to vary without actually interrupting the primary circuit in which it is placed. A portion of this circuit forms the primary coil of an induction coil, a portion of the line wire being the secondary of the same coil. A peculiar feature of this coil I found to be the unusually high resistance of the secondary coil, which was greatly in excess of that ordinarily used with the "Blake" or "Edison" variable contact transmitter.

The line wire was substantially of the sort comonly used with other forms of telephone; but I observed one marked difference between the arrangement of it and that of any other line which I ever knew of as being employed for the electric transmission of speech. This difference lay in the fact that the main line or line wire was a permanently discontinuous or "broken" circuit, in fact not a circuit at all in the sense of a return either by wire or through the earth. This peculiar construction was, as I saw, a necessary one for the operation of the receiving instrument, in which the line wire terminated. This consisted of a pair of stretched diaphragms arranged opposite each other by parallel planes, but separated by a thin intervening annulus of hard rubber. One of the diaphragms was, in all the forms of the instrument I examined, the terminal of the line wire. The other plate, which, when caused to vibrate by the electric changes of the first, produced the speech or words that had been transmitted, was variously connected in different forms of the instrument to avail of various means of increasing its electrical charge. In one form of the instrument this plate was connected with the body of the listener through the handle of the telephone. In another case the other end of the line wire was attached to this second

plate. I did not observe any material superiority of action in one form over the other. In each case the articulation was clear and distinct, particularly so in the case of those combinations of sibilants which have heretofore always been found difficult to transmit telephonically.

The "Dolbear" telephone system is not in any sense a modification of that known as the "Bell" system, in which I include generally all speaking telephones that I have heretofore known. It is based upon a different property of electricity, and that different property in turn is put to a different use.

The external features of the two systems have this in common: that the speaker speaks against the vibrating body, the hearer listens near another vibrating body, and the sounds transmitted are transmitted by electricity. And these characteristics will, in my opinion, as a matter of physical necessity; be found in any apparatus that can be or will be devised for the electric transmission of speech, however widely its principle of operation may vary from any we now know. But the *kind* of electricity, or, more properly speaking, the property of the electricity employed is different, the work done by it is different, and the apparatus by which it is done is different.

The laws of electrical attraction, arising from differences of potential, on which the operation of the Dolbear system depends, have been matter of scientific knowledge for many years, but the application of them to the electrical transmission of speech is not only novel, but so far as my knowledge extends, entirely original. Unlike the principles of electro-magnetism and electro-magnetic attraction, which have been for many years under careful study, and embodied in many forms of apparatus for performing many kinds of duty, even including that of producing sound, the phenomena of electrical attraction before Prof. Dolbear's invention have been studied and investigated only in the laboratory or the lecture room, and no attempt, so far as I know, had ever theretofore been made to practically utilize that force to perform any mechanical duty whatever, except the testing of fuses.

For the purposes of producing sonorous vibrations of a diaphragm, the use of variations of electric potential cannot properly, I think

be regarded as the known substitute or equivalent of the use of magnetic variations as employed in the Bell telephone and described in his patent. The capacity of varying electric potential to perform such a duty in kind or in degree had not, I think, been demonstrated till it was done by Prof. Dolbear.

MOSES G. FARMER.

UNITED STATES OF AMERICA,

STATE AND DISTRICT OF MASSACHUSETTS, } ss.
COUNTY OF SUFFOLK }

At Boston in said county this twenty-seventh day of December, A. D. 1881, personally appeared Moses G. Farmer, and made solemn ath that the foregoing affidavit, by him subscribed, is true.

Before me,

J. HENRY TAYLOR,

Notary Public.

AFFIDAVIT OF HENRY C. BUCK.

HENRY B. BUCK, of lawful age, being duly sworn, says,—

My name is Henry C. Buck; age thirty; reside in West Somerville, Mass.; I have been associated with Prof. A. E. Dolbear (except a few months in 1876-7) since 1875 in studying and experimenting concerning the laws of electricity, sound and magnetism. For the last four years my special attention has been given to the construction of and experimenting with electric speaking telephones.

The permanent magnet telephone, the electrophone, the rotaphone, several varieties of telephonic transmitters, and the new Dolbear system were placed in my hands by Prof. Dolbear to develop, aud they have, each in turn, received my undivided attention.

All telephones actuated by currents necessarily require to be sensative to very feeble currents, because, unless the receiver respond to slight variations in the strength of the current, it cannot reproduce the more minute air vibrations of speech.

Hence any currents, even if very weak, traversing them, other than those needed for the transmission of speech, are mischievous in their effects.

A theoretically perfect telephone must exclude all electrical conditions, except those which are to do the required work in the transmission of speech.

Long before the invention of the telephone it was well known that at times accidental currents of electricity were found upon telegraph lines with sufficient strength to work ordinary Morse instsuments, and they had even been employed for that purpose. Moreover these accidental currents occasionally became so strong, and likewise so variable, as to absolutely prevent the use of lines for telegraphic purposes.

It was not known, however, that such currents are continually present on all such lines ; differing from the desired currents only in strength.

Since the invention of the telephone it has been discovered that whenever the two ends of a conducting wire are grounded at some distance apart, currents of electricity will traverse the wire with a strength and direction determined by the continually varying electric potential of the two localities. These differences in potential arise from natural causes, as do other electric disturbances, such as thunderstorms and Aurora Borealis, and they are always present in some degree, and often sufficiently to seriously impair and not infrequently to destroy the efficiency of the magneto-telephone. When one terminus of such a wire is grounded near the place where another wire is grounded, and this other wire is employed in electric transmission, as a telegraph wire, the electric potential at such terminal will charge the ground for many rods. These electrical charges will give rise to currents of electricity in the first-mentioned wire.

Hence, for instance, if Morse signals are being sent from Boston to New York, thereby greatly varying the potential of the ground in Boston and vicinity, any wire with one of its ends grounded anywhere in Boston, and the other grounded at a distant place, as at Salem or Lowell, will have similar currents set up in it, and a telephone included in such circuit will enable one to hear the signals that are

being sent to New York. If this line be used for telephonic purposes, these Morse signals will act as an interference to the proper transmission of speech. It is owing chiefly to these two interfering agencies that the telephone has been hitherto restricted to relatively short distances. Again, the fact that a current of electricity in one circuit or conductor will give rise to a current in an adjacent parallel conductor, prevents, in a great measure, the use of ordinary telephones on lines adjacent to telegraph lines.

These difficulties in telephony must be overcome in one of the three following ways: —

(1) By neutralizing in some way these deleterious currents. To accomplish this, many ingenious methods have been proposed, but with only partial success.

(2) By excluding such currents from the line, which can only be done by breaking the circuit.

(3) By making a telephone which is not affected by them.

The new Dolbear telephone meets the last two requirements; for (1) the circuit is broken within the receiving instrument by the practically infinite resistance of a film of air, and consequently these deleterious currents are excluded; (2) it is operated not by currents of electricity at all, but by high charges of static electricity.

The importance of breaking the circuit will be clear from the following diagram, where B represents Boston and X some point far enough away to be wholly unaffected by the currents from wires grounded in Boston.

Suppose the difference of potential between B and X to be sufficient to give a current through a continuous conductor grounded at B and at X of a certain strength. Now, suppose the conductor to be cut at D, and one of the Dolbear receivers to be put in the line. Then there can be no current from B to X, unless the difference in potential between these points be so great as to cause a disruptive discharge between the plates at D, which is very many times more than it ever is in fact. The Dolbear telephone D will be materially

benefited by reason of the difference of potential between B and X, because that difference will keep both plates constantly charged, and therefore in better condition for doing their work. The only disturbing influence will arise from changes of the potential at B or at X. If both rise or both fall equally, it will not affect the Dolbear telephone at all. If there be any change of their relative electric tension, there will be a slight effect, but no practical effect, because any change of electric potential of the plates. generated by any fluctuations of potential at B or at X which can occur in practice, will be too slight to have any practical effect upon the Dolbear receiver. Now, if a magneto receiver be used instead, there will be a current between B and X, the strength of which will vary as the potential at B varies from that at X, and the current will tend constantly to rapidly equalize the two; but as the causes which created the difference of potential between B and X do not cease to operate, and operate irregularly, there will be a continuous but very irregular current passing through the magneto-receiver, which will seriously affect, and may wholly prevent, its proper operation.

Experiments with the Dolbear telephone on actual lines varying in length up to over two hundred miles, made from time to time, have corroborated the expectations which the above conditions justify. When tested on such lines, even under very unfavorable conditions, it was found to be not subject to the difficulties I have mentioned. For instance, in England, between London and Norwich, — one hundred and twenty-five miles,—experiments were made under my personal direction, to test its capabilities. No effects were peceived from extraneous currents, and the receiving telephone gave no sound except the words of the speaker, which were plainly heard.

These experiments were performed during business hours, with an ordinary telegraph wire, exposed to very great induction from many other telegraph wires, and upon which similar attempts with various magneto-telephones had often been made, but never, as I was told, with any success.

I have recently tested the Dolbear system on a line of 256 miles long, from Boston to New York, I being in New York, and Prof.

Dolbear in Boston; and found that there was a marked difference between the potentials of Boston and New York, caused mainly, as I believe, by the grounding of many more wires in New York than in Boston. The wire used was one of the American Rapid Telegraph Company's wires, and there were two cables forming part of it. Conversation was readily carried on, and extraneous currents did not impair the efficiency of the instruments. The magneto-telephone was also tried on this occasion, but the effect of the extraneous currents was far more than enough to drown all vocal sounds which could be sent by the transmitter.

I produce two receivers, marked "Exhibits Receiver 1," and "Receiver 2." The resistance of the secondary coil used with them should be about 3000 ohms. The battery used in the primary circuit should be a constant cell of low resistance. It is immaterial whether both plates of the receiver, or only one of them, be connected with the secondary coil; provided the plate not connected be charged or electrified in some way. In receiver 2 only one plate is connected with the secondary coil, and the other plate is electrified by induction from the plate which is connected, and this induction is given full effect by connecting the plate not in connection with the secondary coil to the metal band on the handle of the receiver; for this metal band being in contact with the hand of the listener, the body of the listener acts as a reservoir, so that the moment the terminal plate of the induction coil is electrified, the electricity of the plate not connected with the coil is distributed, the positive electricity of the plate being repelled if the charge be negative in the terminal plate of the coil, and *vice versa*.

In the diagram marked fig. 6, referred to in the affidavit of Edward Davis, the plate not connected with the secondary coil is grounded but there is no current from ground to ground, and Mr. Davis is wholly in error if he means to say in substance that any current passes through the receiver. When the plate connected with one end of the coil is charged, say positively, the opposed plate connected to earth receives a negative charge. If the spot where this plate is grounded happened to be charged, the plate will be correspondingly charged, as I have before explained.

In using the receiver No. 1 it is difficult if not impossible, to notice any difference whether both plates or only one be connected with the coil, provided the finger be placed on the post in connection with that plate not connected with the coil. If one of the plates of this receiver — it is immaterial which — be disconnected from the coil without putting the finger on its post, the receiver will still give out distinct and clear speech, but not so loud as if the finger be placed on its post, or the disconnected plate be artificially charged.

Mr. Davis is mistaken in several respects in his description of the transmitter. I do not know which one he saw, as many, each differing slightly from the others, have been used on the line connecting the office of Mr. Holmes and the rooms of Prof. Dolbear. But I have no recollection of any with the lead weight described by him, or with the pivots between two uprights, shown in figs. 2 and 3 of his affidavit. It is possible a weight may have been tried without my knowledge: but I feel very sure that it never was tried at all, and am certain that it was never used for any length of time. I never have seen any transmitter with the lead weight, or with the pivots between two uprights, and I have no doubt that I should have seen them if they had ever been used. A great many experiments have been tried with this line, for it was constructed solely for that purpose, and although it is possible that the effect of a weight, as shown in fig. 2 of Davis' affidavit, may have been tried by attaching such a weight temporarily, I never heard of it, and I see no necessity for it.

H. C. BUCK.

UNITED STATES OF AMERICA.

DISTRICT OF MASSACHUSETTS, } ss.
COUNTY OF SUFFOLK. }

Subscribed and sworn to at Boston in said district this ninth day of January, A. D. 1881.

Before me,

[SEAL] J. HENRY TAYLOR,
Notary Public.

which those variations were due, originated with Mr. Bell, was first directed by him, enabled him for the first time to transmit speech, and is precisely that which is claimed as novel in the fifth claim; the Dolbear apparatus transmits speech by employing them and causes them by the action of the voice on the transmitter.

The defendants' affidavits also enumerate the differences of construction which they conceive to be important so far as apparatus is concerned. They are confined, as has already been seen, to the receiving part. Each has a device by which "electrical variations, corresponding in form with the air vibrations produced by the utterance of speech, are thereby set up in the line wire" (to use the expression of Prof. Trowbridge), and are converted into corresponding sound vibrations at the receiving station. Both of them do this by employing these "electrical variations" to impart to an elastic plate at the receiving end corresponding vibratory motions. Both of them do this by exposing that plate to an attraction which is varied by and therefore in accordance with those "electrical variations." It is essential for both that this should be so. The difference is, that in the Bell magneto receiver the "electrical variations" pass around the core of a magnet, the attraction between which and the plate is thus and thereby correspondingly varied, and in the Dolbear condenser receiver the "electrical variations" pass into a plate of metal which is thereby correspondingly charged, and the attraction between which and an adjacent piece of metal is thus and thereby correspondingly varied.

This is substantially what is stated in Mr. Pope's affidavit at the top of p. 20 and the bottom of p. 21.

Considering the phenomena which take place in the operation of the receiver, I find that the only difference which is stated is that in one case the electrical variations of special form which are caused at the receiving station by the operation of the transmitter and the electrical conductivity of the line wire serve to vary the attractive power between the core of an electro-magnet and a plate, and in the other these "electical variations" are caused to vary the attractive power between a mass of metal and a plate. In both cases, however, the fact is, and it is essential, that the variations in attraction (and consequent motion) do and must correspond to the "electrical variations" which cause them.

Undoubtedly, electricity possesses two well known powers or capacities or properties, by virtue of which it has long been used to produce attraction; one is, that by virtue of which it causes an iron bar around which it passes to attract such an iron plate, and another is that by virtue of which a body electrified by it "will attract other bodies except such as are electrified by like electricity." One of the receivers utilizes one of these properties as a means of converting electrical variations into corresponding sound waves, and the other utilizes the other as a means for the same purpose.

Mr. Farmer says, referring to what he calls the "Bell system" and the "Dolbear system" (p. 29): "But the kind of electricity or, *more properly speaking, the property of electricity, employed* is different, the work done by it is different, and the apparatus by which it is done is different."

I read this as a statement that, "properly speaking," both employ the same kind of electricity, but utilize different properties of it. The work done, however, is not different; in both, it consists in producing similar sonorous vibrations of an elastic plate. I understand also that Mr. Farmer's statement is confined to the receiver alone; for the other witnesses for the defendants state that all other parts of the apparatus are substantially the same. Moreover, many properties of electricity are employed: as those which concern its generation, the mode of varying it at the transmitting station, and the property by which variations caused at one end of a conductor are propagated to the other without material change. These properties are employed by both as necessary to the operation of the apparatus of each.

All these properties and the manner of using them being the same in both, the difference consists in this, that when by virtue of these properties and the particular construction and operation of the transmitter and line wire (being the same in both), the electricity reaches the receiving end in precisely those measured variations of quantity which Mr. Bell was the first to produce and which are essential for speech, the one person utilizes one long-known property of electricity to make these variations perceptible to the ear, and the other uses another long-known property.

This is correct, but it is not all; I add to this the fact that it was

known before Mr. Bell's time that both these properties might be used as a means of making electrical variations sensible as sound vibrations.

I do not mean to say that, before Mr. Bell's time, condenser receivers had been used for articulate speech, because I believe that no man had transmitted articulate speech electrically before Mr. Bell; I mean that before his time such receivers were used to convert into sound waves such electrical variations as had been produced, and that such condensers as were then used for that purpose will practically act as receivers of articulate speech when substituted, with their adjuncts, for the Bell magneto receiver in well-known forms of the Bell apparatus. Mr. Dolbear's variation in construction from those old condenser receivers may have improved their operation, but has not essentially changed its character.

The defendants, if I understand their affidavits, assert another difference to be, that Mr. Bell produces currents, and that Mr. Dolbear does not produce currents, but merely variations of electric potential, and that this is important. Mr. Pope says (p. 25), in reference to the respective transmitters, that they "are corresponding elements in their respective systems of apparatus. As already mentioned, either of these elements may be used in the Bell system to produce undulatory currents, and when so used they are the substantial equivalents of each other; but Dolbear does not use either of them to produce an undulatory current [*Mr. Pope is here speaking of currents in the line wire alone*], he uses the transmitting circuit to produce a variation of electrical potential."

Mr. Dolbear says (p. 9): —

"The electric variations utilized in my method are radically different from those used in Bell's method. In Bell's method variations in current strength are essential, while in my method the electric variations are static." Referring to the phenomena which take place in the induction coil, he says, "The secondary coil will become electrified, one end being positive, the other negative, — that is, the ends will be at different potentials, — and their potentials will vary instantaneously at each and every variation of the current strength in the primary coil, and there will be no current, but simply electric tension or electric pressure in the secondary coil."

This is an imperfect statement of what takes place. In the secondary coil itself a current is compelled or forced into existence by each varia-

tion in the magnetic condition of the core. This current, which is in a large coil, very strong though very transient, heaps up, if I may use this expression, towards one end of the coil all the positive electricity which the wire possesses, and towards the other end all its negative electricity; and it is this current which causes the difference of potential, or, as Mr. Dolbear calls it, the electric tension or electric pressure at the two ends. This is the generally accepted statement of the operation.

Mr. Fleeming Jenkin, in *Electricity and Magnetism*, speaking of electrical induction from magnetic variation, says (p. 76): —

"In the broken circuit, on the contrary, the current is not produced by a difference of potential between different parts, but the electromotive force drives positive electricity to one end of the wire and negative electricity to the other, producing a difference of potentials which will send back a reverse current as soon as the inducing action of the magnet is over."

Thus the potentials at the terminals of the coil are the result of a current. The potential of either end, when brought to bear on a conductor subject to no other electric force, will in turn produce a corresponding current. That both of these are true currents is shown by the fact that a magneto receiver will be affected and will speak if its coil is looped into the central portion of the secondary helix, and will also speak if its coil forms part of a conductor between either terminal and a neutral body or any body of different potential.

If it were true (as it is not) that there were no currents in the Dolbear apparatus, it would not constitute a departure from what is set forth in Mr. Bell's fifth claim. That claim refers to "electrical undulations similar in form to sound waves." I do not find that the language of the claim limits it to variations in currents, and excludes variations in potential, in cases where the voice of the speaker compels both to follow the same law of variation, and thereby produce the same ultimate result. But in truth Mr. Dolbear cannot obtain variation of potential in his apparatus without obtaining corresponding currents. He does, in fact, obtain currents both in the local circuit, and in the line wire; in both they are not merely incidental, but essential to the transmission of speech by his apparatus; and in his apparatus they are similar in form to the sound waves.

Circuit Court of the United States,

DISTRICT OF MASSACHUSETTS.

IN EQUITY.

AMERICAN BELL TELEPHONE COMPANY
v.
AMOS E. DOLBEAR ET AL.

AFFIDAVITS IN REPLY ON MOTION FOR PRELIMINARY INJUNCTION.

AFFIDAVIT OF CHARLES R. CROSS.

In my previous affidavit, I stated that electrical undulations, similar in form to the sound waves, were produced in the Dolbear apparatus by the sound waves themselves at the sending end, and were the cause of the sound waves heard at the receiving end. I do not understand that this is denied by the defendants' affidavits.

I find therein, however, some statements relating to the electrical phenomena which, it is said, there take place, coupled with the assertion that, in the opinion of the defendants' witnesses, these alleged phenomena are not in certain respects the same as those which they find in what they call the "Bell system." I do not find in those affidavits any attempt to define what they mean by the "Bell system," by reference to the fifth claim of Mr. Bell's patent 174,465, except on p. 16, of Mr. Pope's affidavit.

In my opinion, the conclusion that they are not substantially the same could not be drawn from the facts which those affidavits assert. I am quite sure, moreover, that the defendants' witnesses are in error in the assertions of fact on which they base their conclusions, as I understand them from the affidavits.

Mr. Pope says (p. 21) : —

"The apparatus of Dolbear consists of an inducing magnet at the transmitting station surrounded by a coil of wire which is continuous with the linear conductor. The core of this magnet is provided with an auxiliary coil, a local battery producing a constant voltaic current, a varying resistance and a diaphragm or other body to respond to the movement of the air particles, which diaphragm, through the intermediate action of the parts just mentioned, acts to vary the degree of magnetic energy in the inducing core. Thus far the apparatus of Dolbear is substantially the same as the apparatus which is employed in the telephones in general use."

This statement is correct, because the elements there mentioned, to wit, the vibrating diaphragm, the varying resistance, the battery, the primary circuit, the core of the induction coil, — that is, the whole apparatus at the sending station, — and the "linear conductor," "continuous" with the secondary coil, or, as it is more commonly termed, the line wire, leading from the transmitter to the receiver, are the same in both. The part of the apparatus where Mr. Pope finds a difference, I understand to be indicated in the following words, on p. 21, which follow the passage already quoted : —

"The apparatus at the receiving station, however, is radically different from that of Bell in its construction, principle and mode of operation."

This statement must be limited to the receiving instrument itself; for I have found that in fact if the Bell magneto receiver be inserted anywhere in any conductor employed by Mr. Dolbear in any arrangement of his apparatus, it will operate in the same way and with practically the same result as in that arrangement of conductors which has been more commonly used, and which the defendants refer to as the "Bell system"; this use of the Bell magneto receiver does not interfere with the simultaneous use of the Dolbear receiver.

Turning now to the electrical phenomena, I find these statements : —

Prof. Trowbridge says (p. 27) : —

"In both the method of Bell and that of Dolbear, electrical variations corresponding in form with the air vibrations produced by the utterance of speech are set up *in the line wire*. Unless this is done, it is physically impossible that speech should be transmitted by electricity."

Mr. Pope says (p. 19) : —

"The method of transmitting vocal or other sounds over a telegraph line resembles that described in the patent of Bell in so far as the process of producing variations in the magnetic condition of the iron core of the inducing magnet at the transmitting station is concerned. That is to say, these variations of magnetic energy are controlled by *and are correlative with* the vibrations of the air particles which are taken up by the diaphragm or other body."

So far Mr. Pope is correct. He proceeds : —

"But here the resemblance ends. The process of transferring this action by means of electricity to the receiving station, and of causing at that point the vibration of a resonant plate whereby the sounds are reproduced, is radically different."

Mr. Pope puts the last statement conjunctively. It should be divided. The process of transferring the action from the sending station to the receiving station is substantially the same in both; it is due in both to the disposition of electricity to flow from a point of higher potential to one of lower potential; it is possible in both only where the line wire is an electrical conductor; it is caused in both by varying the potential at the transmitting end; and the success of the apparatus is due to the fact that any special character given to the variations of potential at the transmitting end will thereby be impressed upon the electrical changes of all parts in electrical connection or relation with it. The difference in the process of vibrating the plate I will consider presently.

Mr. Pope says (p. 25) : —

"My attention has been called to the statement in Prof. Cross's affidavit, that both the instruments (Bell's and Dolbear's) form parts of an apparatus which, as a whole, transmits speech by means of certain peculiar variations of electrical currents. If this means that Dolbear uses a complete electrical circuit as part of his transmitter, in which circuit, for the purpose of inducing magnetic changes in the transmitting core, such variations of an electrical current are employed as Bell employs in the circuit in which his receiving core is placed, the statement is correct."

Mr. Pope is right in this, though he does not exhaust the whole meaning of my statement, which was intended to apply both to the local conductor and the line conductor, though the latter does not form a ring conductor. It is true, moreover, that the currents in this

primary circuit are "similar in form to the sound waves"; that, unless they were, speech would not be transmitted by the apparatus; and that the special form of electrical variations in this part is the cause of the special form of electrical variations, whether currents or not, in the line wire and in the receiver. Prof. Trowbridge expressly states this.

Mr. Pope's remark which refers to the above passage of his affidavit, "But I do not understand that any similarity of method in the two cases results from it," seems to me therefore to be erroneous.

Mr. Dolbear in his affidavit says: —

Page 6: "It is true that by Mr. Bell's method air waves produced in speaking are caused to vibrate the instrument which holds the electric circuit under its control constantly, so that whatever movement of the diaphragm at any instant may be made will be converted into a corresponding electrical variation on the line wire. And I do the same."

Page 7: "It is a truism that the electric vibrations must conform to the air vibrations which produce them, if the electric vibrations are to be used to produce air vibrations like the first."

If he means by the word "truism" that the correctness of the method announced in Mr. Bell's fifth claim has been recognized ever since he announced it, I agree with him; if he means that it was known before, I do not agree with him; but I do not understand him to assert that it was known or had been practised before Mr. Bell's patent.

It is thus apparent from the statements in the defendants' affidavits that there is no essential difference in the apparatus except in that portion which consists of the receiver; and that in the operation of the aparatus as a whole, and in the electrical phenomena which cause or accompany the transmission of speech, there can be no essential difference, unless it be such as is due to or compelled by the difference in the receivers. The facts which are common to both, in construction and in operation, are essential to the one result which both produce, and did not exist in the operation of any apparatus anterior to Mr. Bell's patent. I am, therefore, of the opinion that, without reference to other similarities or dissimilarities, the fifth claim of Mr. Bell's patent 174,465 is infringed by the use of the Dolbear apparatus. The employment of electrical variations or "electrical undulations, similar in form to the sound waves" to

I will state the electrical phenomena which take place in the use of the speaking telephone apparatus arranged as usually employed by the plaintiffs and using the Bell magneto receiver. I understand from the affidavits (*e. g.*, Mr. Farmer, pp. 27 and 29; Mr. Pope, p. 21) that this is conceded to conform to the fifth claim of Mr. Bell's patent, 174,465. A diagram of it is given as Fig. 1, p. 21, *infra*.

The transmitter is provided with an elastic vibratory plate or disk.

The sonorous vibrations of the air produced by the vocal organs compel this plate to take up vibratory motions of that special form which is characteristic of the articulate sound produced.

Every movement of this plate causes in a battery circuit a corresponding variation of resistance, and consequently a corresponding variation of current.

This causes a corresponding variation of magnetism in the core of the induction coil.

This causes a corresponding transient current, of momentary duration only, to arise in the secondary helix, whereby the electricity of the secondary helix is compelled to flow towards one end of it, thus raising the potential at one end above its normal value and lowering it at the other below its normal value.

When two bodies of different potential are joined by an external electrical conductor, electricity is transferred or flows with great rapidity from the point of higher to the point of lower potential, until an electrical equilibrium is established.

With a given apparatus in which the distant body is subject to no electrical forces except those due to operations at the sending end, the flow depends upon the potential of the body at the sending end, upon the amount of electricity supplied, upon the time during which it is supplied, and upon the capacity of the receiving body to receive it; the electrical change at the distant end is the consequence of the flow and of nothing else.

Thus, control of the electrical condition at one end of a long, slender (and therefore cheap) conductor enables the operator to control the electrical condition of a far-distant end, not instantaneously, but with an interval which is so excessively short that it cannot be readily noticed under ordinary circumstances.

These two properties of electricity fit it for the rapid and cheap transmission of intelligence by appropriate signals.

When the electricity arrives at the receiving station, it there affects a special instrument provided with a vibratory plate in contact with the air and so constructed that every electrical change which reaches the instrument gives to its plate a motion which in turn imparts a corresponding motion to the surrounding air. It does this by attracting this plate more or less towards a neighboring body which is or will act substantially as if it were immovable. While the attraction is increasing, the plate moves in one direction; while decreasing, it moves in the other.

Each member of this system is found originally in a state of rest or equilibrium. The voice does work in disturbing these by the application of a disturbing force; to this (and its effects) are due the motions and changes which produce the desired result.

The transmission of speech by this apparatus offers therefore a problem in dynamics or kinetics and not in statics.

The spring or lever in a piece of mechanism, when at rest, will support a weight in equilibrium; the study of them in that condition is a branch of statics. Apply to them a force *ab extra* which causes them to move and to move the weight; the study of the operation of the mechanism in this condition of motion belongs to kinetics.

The electrical changes in telephonic transmission are continuous, not intermittent; continuous, however, not in direction, but in succession. The sonorous vibrations of the air do not consist in a motion of translation continually onward, but in a to-and-fro motion, very short, very rapid and without cessation. In the use of the magneto transmitter the currents are alternately to and fro; with the battery transmitter in direct circuit the current does not go on continually increasing, or continually decreasing, but alternately rises and falls; when the battery transmitter is used with an induction coil, the currents are alternately to and fro, as with the magneto transmitter.

This alternating change or motion is implied in the term "undulation" or wave motion.

Sir George B. Airy (on *Sound*, London, 1871) says, p. 22, that

the "general conception of a wave" is that "the nature of the motion is such that the movement of every particle is limited while the law of relative movement of neighboring particles is transmitted to an unlimited distance either without change, or with change following a definite law."

"In all wave motions there is one general character; it is that a state of displacement travels on continually in one direction without limit, while the motion of each individual particle is, or may be, small and of an oscillating character. And this is the general conception of a wave."

Mr. Bell's invention did not lie simply in causing motion, but chiefly in the special character of the electrical changes which he directed; viz., that the electrical undulations shall be similar in form to the sound vibrations to which they are due. By this means he caused the special kind of sonorous vibrations at the receiving end which no one before his time had known how to produce.

The Dolbear apparatus consists of a transmitter, battery, primary circuit, core of induction coil and secondary helix thereof substantially the same in character as the ordinary form of the Bell. A diagram of it is given in Fig. 2, p. 21, *infra*.

All the phenomena which I have described take place in the Dolbear in the same way as in the more common Bell apparatus.

These phenomena in both are due to the same causes, and to the same properties of electricity.

One result in both cases is (considering now the case of a single charge) a rise of potential at the terminal 1.

This rise of potential determines a current towards any body of lower potential, to which it may be connected by a conducting wire.

If terminal 1 be joined by an electrical conductor to any body of lower potential, then electricity will flow from 1 along that conductor to the other body.

This flow is termed a current.

The point 1 may be so joined to a body A, in which case the flow will be towards A until it is "filled up."

If it be joined to the terminal 2, the flow will be towards 2. But it will be a flow or current in both cases.

In both cases it will be the difference of potential which will cause

it and every variation of potential or electrical condition of the body at the transmitting end and will cause and will therefore control the flow or current and its effects at the receiving end.

In both cases the control of the transmitting end will for that reason control the changes at the receiving end.

All that is true of the Dolbear conductor and apparatus as of the Bell; and it is because it is true that the Dolbear apparatus can transmit signals the character of which can be determined by the operator at the transmitting end.

Mr. Bell's method is defined in the fifth claim of his patent 174,465. Electrical signals generally are given by electrical variations. In this claim, Mr. Bell pointed out as the distinctive feature of his method that the electrical variations in their successive changes should conform to the law which expresses the vibrations of a particle of air engaged in producing the sound to be transmitted; the apparatus was to be one in which the action of the voice should produce this special type of electrical undulations. He was the first who had pointed out this method (or any method) competent to transmit speech by electricity. His novel result was due to this novelty of method. Mr. Dolbear's apparatus accomplishes this same result, because in action it conforms to and employs this novel method, which is stated in Mr. Bell's patent and claimed as his invention in his fifth claim.

A device at the receiving end which will there convert into sound waves the specially formed electrical undulations which have reached it is an essential portion of the apparatus. Mr. Bell employed what is called a magneto receiver; Mr. Dolbear employs what is called a condenser receiver. It is true that the two are not identical as independent devices. But this does not change the method employed nor the essential character of the apparatus as a whole. For in each apparatus the transmitter is the same, and performs the same function, to wit, produces the same character of electrical variations; the line wire is the same and performs the same function; the one receiver is used in place of the other because it can transform the electrical variations into sonorous vibrations of corresponding character.

As I understand the affidavits filed by the defendants some of

them assert that Mr. Bell uses "currents of electricity" and that Mr. Dolbear does not.

I have already stated that there is nothing in the language of Mr. Bell's patent, nor in the nature of that part of the novelty introduced by him which is essential to the novel result, that excludes from his claim electrical undulations which are not "currents," if such there be. But in fact currents are present in the local circuit and in the line in the Bell and in the Dolbear wire; in the apparatus of both they are essential to any operation of the instrument; neither will transmit speech unless the current variations are similar in form to the sound waves; in both the essential function of the transmitter is to produce this particular form of current by the action of the voice. It is only when these special articulating currents have reached the receiver that any difference begins, which is material to the operation *of any part* of the apparatus.

The current which I refer to in the line wire is that flow of electricity which the transmitter causes to or from the receiver.

When the terminal of the induction coil is connected by the line wire with the receiving end of the line and the potential of the terminal is suddenly raised, electricity flows along the conductor until so much has flowed that the whole conductor, including the distant end, has been raised to the same potential, if the flow is allowed to continue so long.

If the conductor to be filled, either the line wire or the metal plate or other body at the distant end, is of large capacity to receive and hold electricity, as compared with the ability of the line wire to convey it, and if the supply of electricity furnished for transfer is large, a considerable time will be required for the transfer, and the current will be of long duration.

Thus if all the electricity which the earth is capable of holding had to be transferred over an ordinary telegraph wire to a reservoir formed of another planet, with any ordinary difference of potential, a very considerable time would be required.

If either reservoir were of small size the flow would continue a short time and would be what is called a transient current.

If by artificial means (as by a voltaic battery) a continued supply of electricity were furnished at one end, and all received at the

other were drawn off, the current would go on until the apparatus wore out. This would be called a permanent current.

But whenever a point at one potential is connected with a point at another by an electrical conductor a true "current" or flow of greater or less duration necessarily takes place.

It is only by means of such a flow that the electrical condition of one end controls that of the other. In the Dolbear apparatus the plate moves towards the body of the instrument on a rise of its electric potential. This is due to a forced rise of potential at the transmitter, which sends a flow of electricity along the line conductor, filling or charging the plate of the receiver and thereby raising its potential.

Upon this topic I will quote from a writer who is distinguished for the extreme precision and accuracy of his statements as well as for his knowledge of electricity. I refer to Mr. Fleeming Jenkin's work on *Electricity and Magnetism*, first published in 1873. My references are to the pages of the edition of 1876.

Page 26: "Difference of potential is that difference of electrical condition which determines the direction of the transfer of electricity from one point to another; but electricity cannot be so transferred without doing work or requiring work to be done, hence the following definition: Difference of potentials is a difference of electrical condition, in virtue of which work is done by positive electricity in moving from the point at a higher potential to that of a lower potential; and it is measured by the amount done by the unit quantity of position electricity when thus transferred."

Page 39: "If two electrified conductors A and B, which are at the same potential, be joined by a wire, no disturbance in the electric distribution in the system will take place, unless indeed the wire be of sensible size relatively to the other conductors, and at a different potential; but, assuming the wire to be small, or at the same potential as A and B, the electricity on the bodies after being joined will be in equilibrium as before, the necessary condition of equality of potential throughout being satisfied. If, on the other hand, A be at a higher potential than B, positive electricity must, when the connection is made, flow from A to B, to re-establish electric equilibrium. The amount of the electricity thus transferred must be such

as will restore the equilibrium. It will be great when the difference of potential is great and when the size of the bodies is large, and small under the opposite conditions. The existence or continuance of the flow of electricity from one point to another depends solely on the difference of potential between the points. The magnitude of the conductors has only one influence in the result, by requiring that a larger quantity of electricity shall flow to re-establish equilibrium."

Page 52: "*Current.* Electricity has already been frequently spoken of as redistributing itself over a given conductor, or moving from one conductor to another along a wire; and we may with propriety speak of the current of electricity by which the redistribution is effected." . . . "By using two large conductors A and B, or two Leyden jars of large capacity, and electrifying them with a frictional electrical machine of considerable size to a high potential, a considerable quantity of electricity may be accumulated on A and B, and a considerable current will flow from A to B when they are joined."

Page 80: "Any change in the distribution of the statical charge of electricity on the surface of bodies produces currents until the redistribution is completed and equilibrium is restored. We find no difference of kind between these currents; they all have the same properties but combined in very varying degrees."

Page 74: "The conductor in which the current is induced need not form what is called a closed circuit, *i. e.*, such a conductor as is formed by a ring of wire round which the current can continue to flow permanently if a permanent electro motive force be kept round it, as distinguished from a broken circuit, such as would be formed by a ring of wire incomplete at one or more points, where the presence of air or other non-conductors would stop any permanent current; but although the induced current will be very different in the two cases of a closed and open circuit, it will be produced in both. In the closed circuit we may have a current induced without difference of potentials between the parts. We cannot have difference of potential between two parts of a conductor without a current ensuing; but we may have a current due to electro motive force, without any difference of potential."

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as will restore the equilibrium. It will be great when the difference of potential is great and when the size of the bodies is large, and small under the opposite conditions. The existence or continuance of the flow of electricity from one point to another depends solely on the difference of potential between the points. The magnitude of the conductors has only one influence in the result, by requiring that a larger quantity of electricity shall flow to re-establish equilibrium."

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Page 78: "When the poles of the galvanic cell z c are first joined at N and M to the wires A, B, C, D, electricity will rush from the cell into the wires. This electricity has to charge each portion of the wires statically. The current begins close to the cell some time before it reaches the remoter portions of the wire. It flows at different rates through different sections of the wire according to their size, capacity and material."

Page 79: "If the cell be connected with two long wires insulated at the farther ends (as in Fig. 51), or if one pole be connected with the earth and the other with a large, insulated conductor or long wire, we shall have a series of preci-ely similar phenomena, except that the final conditions of equilibrium will be that in which all parts of the conductors being duly charged to the potentials which the cell produces, no further current will flow at all."

J. Clerk Maxwell, *Electricity and Magnetism*, vol. 1, p. 289: "In the case of the current between two insulated conductors at different potentials, the operation is soon brought to an end by the equalization of the potentials of the two bodies; and the current is, therefore, essentially a transient current."

Culley, *Handbook of Practical Telegraphy*, London, 7th ed. 1878, speaking of the discharge of the rubber of a frictional machine through a fine wire, says, p. 7: —

"Before the discharge takes place or the current commences to flow, the electricity is said to be in the static condition; *during the discharge, it is in the dynamic condition, because it there exercises force or performs work.*" "Whenever there exists a difference of potential between two points connected by a conductor, a current passes between them until equilibrium is established."

Preece & Sivewright, on *Telegraphy*, p. 5: "Potential implies that function of electricity which determines its motion from one point to another."

Deschanels' *Natural Philosophy*, by Everett, New York, 1878, p. 558: "A conductor is said to be in electrical equilibrum when there is no electrical force in any part of it; in other words, when it is completely free from currents of electricity." P. 559: "When a conductor is not in electrical equilibrum, currents set in tending to

[illegible] the amount of the electricity thus transferred must be such

restore equilibrium; and the direction of such currents is always from places of higher to places of lower potential."

I have multiplied these quotations, not because I suppose there is any doubt about the fact, but in order to show that the transient flow of electricity between two bodies of limited size at different potentials is commonly spoken of as a current.

I will now refer to the facts which show that it possesses those properties of a current which we have to deal with in the telephone, and which affect the magnet of the magneto receiver.

One method of determining the electro-motive force of a battery (ordinarily looked upon as the furnisher of a "current") is to measure the potential of a condenser or other body to which one pole is connected; when the body is thus charged, its potential, in the case of a plate, is measured by the attraction exercised between it and a body either neutral or negatively charged Convenient statements of this are found in Fleeming Jenkin's work, Chap. V. and Chap. XIV., and p. 267, and in Sir William Thomson's *Electrostatics and Magnetism*, p. 281.

The capacity of a condenser or other body, or the amount of electricity which it can contain, is commonly measured by allowing it to discharge itself through a circuit which includes a galvanometer. See Jenkin, p. 162.

The condenser shunt, a well-known device, depends in part upon the fact that the transient current due to the inflow or outflow to and from an electrical reservoir of moderate capacity (a condenser) acts upon magnets as other currents do, or combines with other currents in acting on magnets.

One of the recognized and usual modes of ascertaining the position of a break in a telegraph line is to consider the line from the testing office to the break as an empty reservoir, to fill it up with electricity, measure the inflow by a galvanometer and thus calculate the length of wire from the amount of current required to fill it; or, conversely, to fill that part of the wire and measure the current while discharging. These currents are transient, but they are "currents." Of this usual test Schwendler, *Testing Instructions*, London, 1879, vol. 1. p. 136, says: —

"The capacity of a line is proportional to the quantity of its

Page 78: "When the poles of the galvanic cell z c are first joined at N and M to the wires A, B, C, D, electricity will rush from the cell into the wires. This electricity has to charge each portion of the wires statically. The current begins close to the cell some time before it reaches the remoter portions of the wire. It flows at different rates through different sections of the wire according to their size, capacity and material."

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I will now refer to the facts which show that it possesses those properties of a current which we have to deal with in the telephone, and which affect the magnet of the magneto receiver.

One method of determining the electro-motive force of a battery (ordinarily looked upon as the furnisher of a "current") is to measure the potential of a condenser or other body to which one pole is connected; when the body is thus charged, its potential, in the case of a plate, is measured by the attraction exercised between it and a body either neutral or negatively charged Convenient statements of this are found in Fleeming Jenkin's work, Chap. V. and Chap. XIV., and p. 267, and in Sir William Thomson's *Electrostatics and Magnetism*, p. 281.

The capacity of a condenser or other body, or the amount of electricity which it can contain, is commonly measured by allowing it to discharge itself through a circuit which includes a galvanometer. See Jenkin, p. 162.

The condenser shunt, a well-known device, depends in part upon the fact that the transient current due to the inflow or outflow to and from an electrical reservoir of moderate capacity (a condenser) acts upon magnets as other currents do, or combines with other currents in acting on magnets.

One of the recognized and usual modes of ascertaining the position of a break in a telegraph line is to consider the line from the testing office to the break as an empty reservoir, to fill it up with electricity, measure the inflow by a galvanometer and thus calculate the length of wire from the amount of current required to fill it; or, conversely, to fill that part of the wire and measure the current while discharging. These currents are transient, but they are "currents." Of this usual test Schwendler, *Testing Instructions*, London, 1879, vol. 1. p. 136, says: —

"The capacity of a line is proportional to the quantity of its

charge with a given electro-motive force, which can be found either by measuring the transient current due to 'charge,' or by measuring the transient current due to 'discharge.'"

These measurements are made by means of the galvanometer, which is an instrument consisting of a magnet acted upon by the current. "A galvanometer is an instrument intended to detect the presence of a current and measure its magnitude." Jenkin, p. 187.

The speaking telephone never employs permanent currents in the sense in which that term is generally used, whether the transmitter be of the magneto type shown in Mr. Bell's second patent 186,787, or of the type referred to in the affidavit of Mr. Davis and in the affidavits of the defendants as a battery transmitter furnished with an induction coil (as shown in Fig. 1, p. 21, *infra*). A succession of transient currents follows each other in the wire. The transmitter first raises the potential of that end of the line which is at the sending station, and then lowers it; in one case it determines a current towards the distant end, and in the other case from it. Every time the potential of the sending end rises above that which the distant part possesses (whether it be the normal condition of the latter or that given to it by the last preceding electrical impulse), at the same moment a current is caused from the sending end; each time its potential is forced below that of the distant end electricity flows back again. Thus a succession of currents takes place, each transient considered by itself, but each succeeded by the next without intermission, so that the electrical changes are as continuous as the waves of a continued sound. Each current, considered by itself, lasts much less than one thousandth of a second.

This is equally true of the Dolbear apparatus: transient currents are present; the duration of each and the form of each (so far as the transmission of speech is concerned) are the same in both.

As already stated, when the circuit is in the form of a ring, that is, a wire closed in upon itself, a permanent current can flow in it; when the conductor joins two reservoirs the duration of a current depends upon the capacity of the reservoirs. Those used in the Dolbear apparatus are small and would not maintain a long-continued current. But a long-continued current on the line wire is not required nor commonly used in telephony.

The sending reservoir or source, which is the controlling portion, is the same in both. The receiving reservoir, though small, is large enough for the transient currents on which the operation of the Bell magneto receiver depends. Though small, as compared with the mass of the earth, it is filled and emptied so many times a second that its capacity is sufficient for this purpose.

It is certain that both the charge and the discharge of a condenser or other limited receptacle of electricity is due to, and accompanied by — I may say consists in — a practically applicable and useful flow or current of electricity through the connected wire. Some further examples of this will be given on pp. 28, 29, *infra*.

This is so well settled that, as already stated, a common way to measure the amount of electricity which a condenser holds, or is capable of holding, is to empty it or fill it through a conducting wire and measure the flow by an instrument called a galvanometer, which measures a current by its influence on a magnet.

The galvanometer is not adapted to detect or measure the articulating currents of any telephone apparatus: they are of excessively short duration; and, while they are of a nature to affect a galvanometer, yet the time during which they act is so brief and their reversals (either of direction or of change) are so quick that the galvanometer needle, as usually constructed, is too sluggish to respond to an extent readily perceptible.

The magneto telephone itself is of course sensitive to telephonic currents. I have employed it to ascertain their presence in the Dolbear apparatus with the more confidence, because Mr. Dolbear says, in effect, in his affidavit (p. 9), that variations in current strength are essential for the operation of Mr. Bell's magneto receiver. If I understand correctly the meaning of the first part of page 10 of Mr. Dolbear's affidavit (of which I am not sure), he intends to say that a Bell magneto receiver inserted in the line conductor of the Dolbear apparatus will not there find the kind of energy required to work it; and this assumption appears to be an "emphatic basis" of his belief in a substantial difference between his apparatus and Mr. Bell's more ordinary form of apparatus.

I have tried the following experiments with the following results. I have performed each of them at least twice on different days.

Some of them I have repeated many times in order to assure myself that the results were not due to or affected by any accidental disturbing causes. In all of them which I here state, and in most of the others, the transmitter and receiver were placed in separate buildings; and I assured myself whether speech was transmitted or not by causing the assistant to repeat to me what he heard or what he said; and I frequently caused him when he listened to report his results without informing him of the various changes which were made. In every experiment here stated I also listened myself.

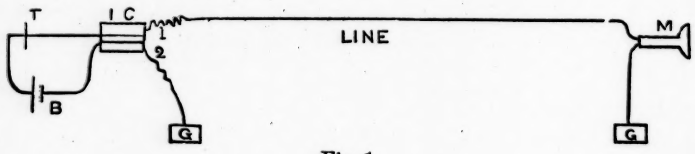


Fig. 1.

I will describe the diagrams I have made, and the instruments used.

The transmitter T was a variable-resistance battery transmitter with a battery B in a local circuit which included the primary of an induction coil (I C). The secondary helix of one coil used had a resistance of 4,000 ohms. I occasionally used a somewhat larger coil, belonging to the Institute of Technology, but found no material difference. G signifies ground, which was obtained on gas or water pipes in the usual way. Fig. 1 shows the ordinary arrangement adopted by the Bell Company for the Bell system with the Blake or Edison battery transmitters. One terminal of the secondary helix is connected to the line and the other to earth. M signifies a magneto receiver, which was of the usual form. In the subsequent figures C signifies a condenser receiver. I used two Dolbear condenser receivers. The first was made at the factory of the plaintiffs and was intended to conform to those made by Mr. Dolbear. I am informed that it was shown to Mr. Dolbear and was declared by him to be properly made. After the defendants' affidavits were filed, I caused copies to be made of the two Dolbear receivers filed by Mr. Buck, and many of the expriments here reported were either originally performed or repeated with these. I did not find any material difference between these and those previously used.

In these experiments I also used instruments which I designate as the Wright condenser, the Ferguson condenser and the Varley condenser. These were made for the purpose of these experiments in conformity to the descriptions given by those three writers and appended to this affidavit. I also used another receiving condenser, which was made during the year 1880 for a speaking telephone receiver in accordance with the direction of Mr. George L. Anders. I saw this receiver during the year 1880, when some experiments were performed with it at the laboratory of the Institute.

The line wire was of the usual size; it was of copper office wire indoors and of the usual line wire size outdoors. The line was not constructed especially for these experiments.

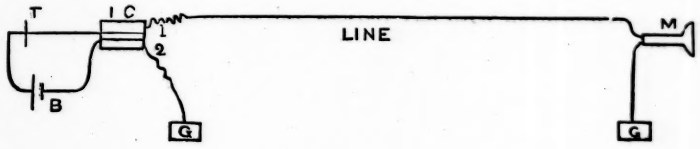


Fig. 1.

Fig. 1 represents the usual speaking telephone connections. With all the coils this gave excellent speech.

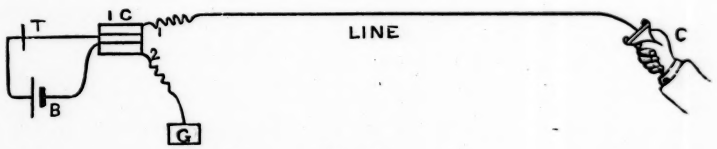


Fig. 2.

Fig. 2 shows what I understand to be the Dolbear arrangement of conductors in the most pronounced form. One terminal of the coil, marked 2, was left in the air, insulated as shown. The receiver was grasped so that the listener was in electrical connection with the back plate of the instrument, but insulated from the first front plate and line. This is the manner in which Mr. Dolbear intends that it should preferably be used. I could understand articulate speech through it. I then repeated the experiment by connecting the terminal 2 of the

coil with the back plate of the Dolbear receiver, but found no change of result. I again repeated the experiment by grounding the terminal 2, and grounding the back plate of the condenser. I did not perceive any substantial difference in the result. I then removed the grounds and held the receiver so that I was not in electrical communication with the receiver at all. Speech was audible, but poor and faint, and hardly intelligible.

In the experiments which I here report, I left the terminal 2 of the coil in the air and insulated, except where I have expressly shown it grounded; and wherever the receiver, or the receiving end of the line, is shown as grasped by the hand, it was so grasped that the operator was in electrical communication with it. I also took the precaution, in all the experiments where the operator was in electrical communication with any part of the apparatus, of causing him to be insulated, by standing on a thick plate of vulcanite placed on a floor cloth of linoleum, though I did not find that such special insulation changed the result. The human body is of ample electrical capacity for any form of apparatus which I used.

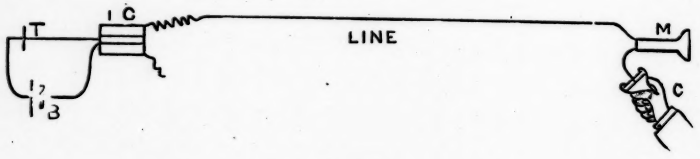


Fig. 3.

In the experiment Fig. 3, the conductors and connections were of the Dolbear character as in No. 2, but a Bell magneto was looped into the Dolbear conductor. There was, under the precautions already named, no ring circuit in the line, and no currents passed through the magneto receiver except such as were due to the capacity of the wire and the front plate of the Dolbear condenser receiver, assisted by the inductive effect of the back plate and connected masses. I heard articulate sentences at the Dolbear condenser and at the Bell magneto receiver, as well as in the arrangements Fig. 1 and Fig. 2 respectively. I have repeated this experiment many times on different days.

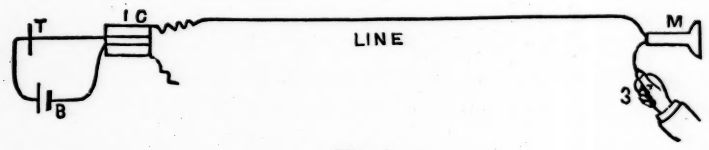


Fig. 4.

With this arrangement, Fig. 4, one terminal of the coil in the air and insulated and the person holding the receiving end of the wire insulated, the transmission was as good as in No. 1.

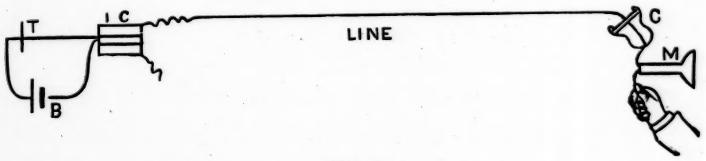


Fig. 5.

Fig. 5. With this arrangement speech was obtained both with the Dolbear condenser receiver and with the Bell magneto. The latter was about as good as in No. 1; the Dolbear acted, with regard to the magneto, like an ordinary condenser.

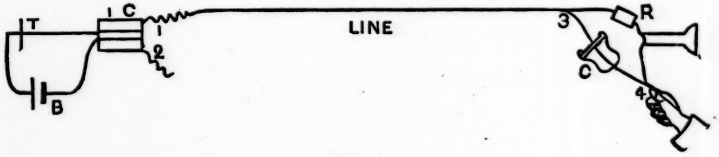


Fig. 6.

Fig. 6. In this I connected the front plate of the Dolbear condenser receiver to the line in the usual way and connected the insulated operator with the back plate by a wire. I passed a shunt or divided circuit around the receiver, and in this branch I placed a Bell magneto-telephone. The electricity passing along the line would come to the point of division 3, and a part of it would pass off through the shunt and the magneto telephone. I placed in this branch shunt an artificial resistance R, of about 80,000 ohms. This offered an

impediment to the too easy passage of the transient current, and therefore the shunt, with this resistance in it, did not much change the electrical condition of the rest of the apparatus from what it would have been if the shunt were not there, but at the same time allowed current enough to pass to work the Bell magneto. With this arrangement I heard speech well in both instruments. Upon removing the resistance R, the transient current of electricity flowed off so freely through the shunt that not sufficient difference of potential was produced between the two plates of the Dolbear to cause an audible effect. The same kind of operation went on in the Dolbear as before; but the action was so much diminished as not to be perceptible to the senses. As resistance was gradually introduced at R, the sound in the Dolbear became perceptible and gradually increased in loudness. The result is what one would naturally expect in the case of a flow of a transient current from the coil, and occurs because of the relations between resistance, potential and current.

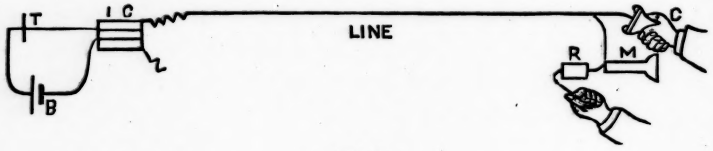


Fig. 7.

The experiment, Fig. 7, depends upon the same principle as Fig. 6. The two receivers were held by different persons insulated from each other. With a high resistance at R speech was heard in both receivers.

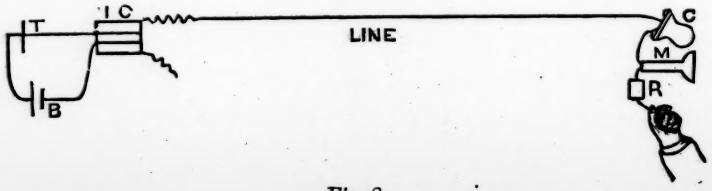


Fig. 8.

Fig. 8. In this experiment the electricity, starting from the coil, flowed to the front plate of the Dolbear receiver, then through the

plate out again, through the magneto receiver, then through a high resistance to the operator. The two receivers were held by different persons. That a current did actually flow through the plate of the Dolbear receiver is shown by the fact that what came out from it worked the magneto receiver while the resistance R kept the potential between it and the coil high enough to produce clearly audible effects in the Dolbear condenser receiver.

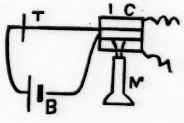


Fig. 9.

I have said in a former part of this affidavit that a current is produced in the secondary helix itself. In the experiment shown in Fig. 9, I used a large coil of about 4,000 ohms' resistance, with the two terminals in the air and insulated, so that there was no external conductor or circuit. In the middle of this coil, as near the exact middle as I could conveniently get at it, I looped in a magneto telephone. From this I got articulate speech perfectly.

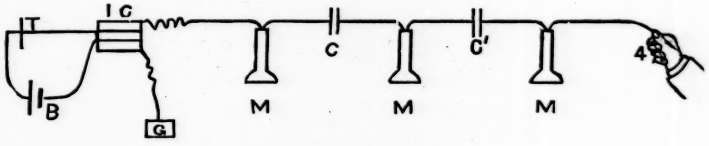


Fig. 10.

In this figure, which represents experiments I have tried, the line was broken by condensers. M represents the ordinary Bell magneto receiver. C represents condenser receivers. The arrangement is a bad one in so far as it entails considerable waste of force, but, using Bell magnetos and Dolbear condensers, all gave articulate speech.

I then placed a Wright condenser receiver at C′ and got speech in all; but it was hardly intelligible at the Wright C′. I expected this, because the electrical capacity of the Dolbear is very much less than

that of the Wright, and therefore the former could not fill it. Then replacing the Dolbear at C by a condenser of ordinary capacity (50 sheets of tin-foil), I got intelligible speech readily out of the Wright at C'. In this case I had the farther end, 4, connected to earth instead of the hand; but I have found in repeated experiments with these instruments that the change is immaterial.

I then replaced the Wright by a Ferguson silvered paper condenser, and got good and intelligible sentences with it as a receiver.

The conclusion and the facts are, therefore, that the Dolbear apparatus transmits speech by causing "electrical undulations, similar in form to the sound waves," which constitute the sound to be transmitted. Currents exist in the Dolbear apparatus. In every part of every conductor contained in it, they exist to an extent which will practically work the Bell magneto receiver.

Quoad the transmission of speech, they exist both in the line wire and in the primary circuit as much as in more ordinary arrangements of telephone conductors. They are in both of a form similar to the sound waves; and it is essential that they should be. They are of this form in the primary conductor; and they must be there in order that they may have the same form on the line wire.

It is true that the currents employed in the more ordinary arrangement of telephone apparatus will not operate the Dolbear. This is not because they are currents, but because they are not of sufficiently high potential. The transmitting coil ordinarily used is much less expensive and powerful, and the grounded circuit allows the electricity to escape so rapidly that the potential never rises to the great strength required for an unsensitive instrument like the Dolbear.

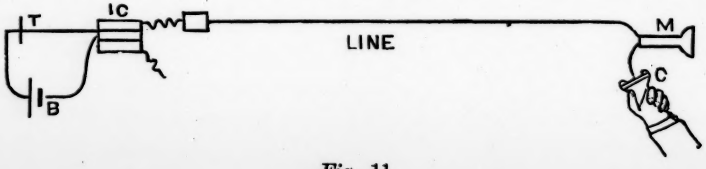


Fig. 11.

Mr. Dolbear says in his affidavit that Ohm's law applies to Mr. Bell's magnetic receiver, and does not apply to his condenser

receiver. I understand this to be a statement that a high resistance impairs or prevents the working of one and not of the other. The effect of resistance on the high tension transient secondary currents in the telephone is not perfectly understood; but the following experiments show that the two instruments do not materially differ in these respects. In Fig. 9 I inserted 200,000 ohms, and this diminished somewhat both Bell and Dolbear, then put in over a million ohms of plumbago resistance; this prevented utterance in the Dolbear, though I got some faint sound in it. But I understood sentences in the Bell magneto receiver with the same conductor. The farther terminal of the Bell magneto was sometimes connected to earth, and sometimes held in the hand in this experiment, but I found no material difference. I then took out the induction coil end, which was of 4,000 ohms, and substituted for it a more powerful coil of 6,260 ohms in the secondary. The increased electro-motive force of this caused enough electricity to pass the resistance in the limited time allowed in a speaking telephone to work the Dolbear receiver and produce effects which were audible and distinguishable.

That such a resistance does not absolutely prevent the passage or flow of a current of electricity is proved by the fact that it did not prevent the Bell magneto receiver from reproducing articulate speech. It would at all not prevent the transmission of "electric pressure," if such a thing exists, any more than the moderate size of a pipe would prevent the maintenance of a steady hydraulic pressure. But if the problem changes from one of statics to one of kinetics, and the operation of the instrument involves the incessant and rapid passage of a to-and-fro current, then any obstruction which, according to Ohm's law, obstructs the flow, would obstruct the operation of the apparatus, whatever might be the nature of the receiver on which the electricity was to act when it arrived.

In this case a high resistance diminishes the quantity which flows through it. The current which is to "fill up" the plate of the Dolbear receiver starts from (or is drawn back to) the terminal 1 of the coil. It flows from that point for an excessively short period and back again for an excessively short period. If the line wire offered no resistance whatever to this flow, the potential of the receiver would rise as high and fall as low as the potential of the point 1, with which it is connected. If, however, the line offers such resistance as to

seriously impede the flow, the full amount will not be able to pass to the receiver during the short time when the point 1 is at a high potential, nor to run out of it during the short time when the point 1 is at a low or negative potential, and the potential of the plate will not rise as high nor fall so low; that is, its range of variation will not be so great as in the former case. If the conductor be broken, and the parts so far separated that one does not influence the other, there will be no flow; if the resistance be infinitely great, the flow and the consequent range of variation will be infinitesimal.

It is clear from this that Ohm's law (or such modification of it as applies to transient currents of high tension) applies to the case of Mr. Dolbear's apparatus. It applies because the apparatus as a whole depends upon the flow of a current of electricity, and because the control of the receiver by the transmitter depends upon that transfer of electricity which is known as a current.

The experiments Nos. 6, 7, 8 show that leakage, due to imperfect insulation, also affects the apparatus seriously. In this case it required a high resistance of 80,000 ohms to retain on the line electricity enough to work the instrument, though probably less might do it. An insulation resistance of one hundred ohms would be sufficient with the magneto receiver on a short line. The extreme high tension of the currents employed increases the difficulty of obtaining the high insulation required.

I have tried two other experiments which show, what indeed has been known for many years, that electrical instruments can work without the passage of a current from the actuating battery to the receiver, and with the current interrupted, provided only that the separate conductors are placed in such relations to each other that every electrical impulse employed in one causes a like electrical impulse in the next. Arrangements of this kind have been adopted in order to guard against earth currents, and for other purposes. This plan has been applied to the Atlantic cables from a very early day. It is due to Mr. C. F. Varley, and is described in an early English patent, and in his United States patent, No. 78,495, June 2, 1868. One form described in Varley's said patent, and also shown and explained in Preece and Sivewright's *Telegraphy*, p. 135, and Jenkin's *Electricity and Magnetism*, p. 335, is represented by the following diagram: —

In this arrangement no current from the battery B ever reaches the line; the cable is normally in a state of electrical equilibrium and at a zero potential.

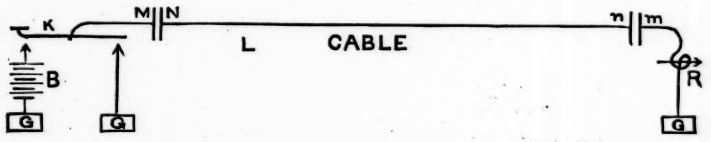


Fig. 12.

In describing this Mr. Jenkin says (p. 336): —

"The line L is attached to the insulated armatures N and *n* of two large condensers; the second armature M at the sending end is connected to a key K by which it can at will be connected with the battery B or with earth; the armature *m* is permanently connected through the receiving instrument R with earth. When, by the key K, M is connected with the positive pole, N is rendered negative by induction; a current flows from N to *n*; *n* becomes positive and *m* negative by induction; and to charge *m* negatively a short current flows from *m* to G through the galvanometer receiver R, making the desired signal in one direction; the current sent through R begins suddenly, is very small, and would gradually die out; the fall in the current is however accelerated by raising the key and putting M to earth. . . . with this arrangement no electricity flows into or out of the cable but by induction; the charge in the cable is rearranged at each signal. . . . Mr. Varley's system has the additional advantage that no permanent earth currents can flow through the line, for the line is not connected anywhere with earth."

The receiving instrument is a galvanometer which works by the influence of a current on a magnet. It may be placed as shown in the diagram or it may be placed in the line between *n* and N. The electrical change which here takes place is a current in the true sense. It is transient, but will work any delicate magnetic instrument, including a galvanometer, which is an instrument distinctively known as a detector and measurer of currents.

Mr. Pope states as follows (on p. 20 of his affidavit): —

"The two methods, in short, avail themselves of two wholly distinct properties of electricity or two wholly distinct electric energies, namely, the so-called dynamic electricity employed in Bell's system, and static electricity employed in Dolbear's system. Their energies differ first, in their intrinsic nature, secondly, in the effects they are capable of producing as regards their natures. The essence of the dynamic electricity is its motion, and the essence of the static electricity is its rest. Hence their respective names. As regards their effect each produces a manifestation of energy wholly different from that produced by the other. Dynamic electricity, by virtue of its motion, produces magnetism; static electricity, by virtue of its lack of motion, produces electrical attraction. These effects, as widely different as the causes which produce them, are respectively used by the two systems. A uniform and continuous magnetic attraction can only be produced from the conversion of electric energy by means of a continuous electric current traversing an uninterrupted circuit. If this circuit be interrupted, the magnetic attraction ceases. On the other hand a uniform and continuous electric attraction can only be produced by means of a continuous difference of potential, which is maintained by a continuous interruption of the conductor. If the circuit be closed, the difference of potential is no longer maintained, and the electric attraction ceases."

If Mr. Pope means by this that electricity at rest can attract and cannot magnetize, he is correct; if he means that a conductor through which a current of electricity is passing cannot attract a body not similarly charged, he is in error; if he means that in the operation of the Dolbear apparatus there is a single instant when electrical changes are not going on, he is in error; for incessant change is the law of its action just as much as when a magneto receiver is used. If he means that electricity does not flow to and fro between the transmitter and the receiver in the Dolbear apparatus, Fig. 2, as much, as rapidly, as often, as in the Bell apparatus, Fig. 1, he is in error. In Fig. 2, as in Fig. 1, a "linear conductor" is provided for that very purpose and none other; and it is as essential in the one case as in the other. The electricity does not stay at home, but travels from the transmitter to the receiver to work the latter.

He is quite right in saying that a continuous current is needed for "a uniform and *continuous* magnetic attraction," and that a continuous difference of potential is needed to produce "a uniform and *continuous* electric attraction." But he does not say, and I am sure that

he would not say, that in either receiver the attraction is "uniform and continuous" or either, for in fact it is the unceasing *variation* in the attraction which produces the sound.

He says that a uniform and continuous magnetic attraction can only be produced by a current in an uninterrupted circuit. I infer from the rest of his affidavit that he means by this a ring circuit. Strictly speaking, he is right in this. But such *transient* magnetic effects as are needed to work a galvanometer or a telephone are practically found in conductors which are wholly insulated by means of condensers or induction coils. This is shown by the ordinary use of condensers in submarine cables, and by the experiments shown in the foregoing diagrams, 3, 4, 5, 6, 7, 8, 9, 10, 12. All of these experiments depend upon laws which are familiar, and I think that any electrician to whom they were suggested would at once perceive that they must result as I have found them to result.

He appears to say that a continuous difference of potential can only be maintained in an interrupted conductor. In this he is in error, for the potential of every part of a given conductor between the two points where the electric energy is applied is changed by the flow of a current; and if the supply is exactly equal to the outflow (so that a steady current is produced), the potential of every part thus charged remains unaltered. The Wheatstone Bridge is based on this property, and is particularly explained with reference to it by Jenkin, p. 243.

It is true that current, as current, does not exhibit the kind of electric attraction referred to and that potential, as potential, does not operate a magnet; but, in Mr. Dolbear's apparatus at least, change of potential and current necessarily accompany each other. It is true, also, that the magneto receiver can be worked with a current due to a moderate difference of potential, and that it is cheaper so to do; and that the alternating currents sent from the transmitting station will produce the high potential required for audible effects in the Dolbear receiver much more easily if the outflow or waste be small or cut off altogether by entirely insulating the line wire.

In fact, however, as I have already stated, the same transmitter in both operates by the same means and in the same way to cause an alternate flow and reflow of current along the conductor to the receiving station. This electricity has two properties and, placing

the two instruments side by side in the same conductor, one property moves one and the other moves the other. The essential novelty to which speech is due, however, is not motion, but the peculiar character of the motion; and in both this is due to the fact that the electricity is not sent from one station to the other in a uniform and continuous flow, but in the form of "electrical undulations similar in form to the sound waves"; and this form is given to them by the voice of the speaker.

I am not sure that I understand the meaning which Prof. Trowbridge on p. 26 of his affidavit intends to convey. Submarine cables present the case where the electricity which starts from the transmitter never reaches the receiver in the ordinary sense, because the line is interrupted by one or more condensers. There is no "circuit," if that word is to be confined to a ring circuit, or conductor joined back to itself. This operates by the disturbance of the static charge of an insulated conductor; but the disturbance is manifested by or takes the form of a flow and reflow of electricity; and this is known as a current, and acts on magnets like a current of equal duration in a ring circuit. The linear conductor or line wire of the Dolbear form of telephone exhibits the same electrical operation as the cable, and both show electricity in motion. Prof. Trowbridge cannot mean, I think, to ignore these facts, and I therefore suppose him to mean that he did not know of any practical application of direct electrical attraction. In other words, the novelty which he refers to is a novelty found in the receiver alone. I also understand him to say that the principles involved in the receiver are well known, and have long been applied in electrometers for measuring purposes, but that he is not aware of any commercial application of the principle before Mr. Dolbear's apparatus.

In my first affidavit in this case I referred to the fact that previous to the date of Bell's patent electrical variations in the secondary circuit of an induction coil were utilized to produce sound by causing vibratory movements in plates. In this statement the defendants consider that I was mistaken. I had in mind three particular pieces of apparatus. First, the receiver of Dr. Wright, described by him in an article in the transactions of the Royal Scottish Society of Arts, 1860–1864, vol. 6., appendix, pp. 185–187. Second, a

somewhat different condenser receiver of Dr. Wright described in *Ferguson on Electricity*, in 1867, p. 68; that description is repeated in Prof. Dolbear's book on the *Telephone*, published in 1877, p. 106. Third, the condenser described by Varley in his English patent, No. 1,044, of April 8, 1870. The two condenser receivers of Wright were placed in the secondary circuit of an induction coil, the primary of which was made and broken in the use mentioned by Ferguson by a Reis transmitter operated by the voice, and the statement made by Ferguson was that the musical note or pitch sung into the transmitter was reproduced at the receiver. In the Varley apparatus, one plate of the condenser was connected to one terminal of the secondary helix of an induction coil, while the primary circuit was made and broken by a tuning fork or other suitable arrangement. The purpose of the Varley was to reproduce in this receiver the pitch of the transmitter in a system of harmonic multiple telegraphy.

The defendants' affidavits refer to only the second apparatus of Wright. I still believe that the operation of those condensers of Wright and Varley was due to the attraction of the plates of the condenser for each other, as the potential of the one connected with the induction coil was raised or lowered, and thus that the nature of the operation was essentially the same as that employed by Mr. Dolbear in his receiver.

Mr. Dolbear and Mr. Pope, in their affidavits, state, if I understand them correctly, three things about the Wright receiver, which is the only one referred to. They say that the sound produced was not due to the charge and discharge of the condenser as those words are always understood in speaking of a condenser, but was due to the rupture of the dielectric by the disruptive passage of a spark from one plate to the other. The difference, of course, would be material in practice, because the condenser would be very quickly destroyed by the latter; and I cannot believe that Mr. Varley proposed to use an instrument which was so quickly self-destructive. The potential specified by Mr. Varley (50 volts) would be entirely inadequate to produce disruptive discharges in his condenser.

Mr. Dolbear and Mr. Pope also, if I understand them, say that the second apparatus of Wright did not exhibit what they call "mass

vibrations" in the plate, and that the Dolbear apparatus does. Finally, they say, or rather give it to be understood perhaps, that the Wright receiver is not capable of reproducing speech, and that no man would be led to believe from what was known of its operation that it would reproduce speech. I think they are mistaken in these views.

I feel confirmed in what I stated in my former affidavit by the opinions expressed by a number of writers of authority who have referred to these condenser receivers and their operation, and by a series of experiments which I have performed on the subject. The first article of Dr. Wright in the transactions of the Royal Scottish Society described a receiver consisting of plates of zinc separated by insulating paper placed between them. He used language there which shows that he then believed that the noise was due to disruptive discharges from one plate to the other. In this, however, I think he was mistaken. The second apparatus of Wright was differently constructed. It was made of sheets of silvered paper placed back to back, the metal here being in the form of thin foil. The only description of this which I know of is from Ferguson, and it gives no indication or intimation that disruptive discharges were considered to be the cause. I presume that during the interval between the two publications, Dr. Wright had found the true cause. I am confirmed in this by the fact that Dr. Ferguson and Sir William Thomson took part in the discussion which followed the exhibition of Dr. Wright's first condenser.

Mr. Pope makes a statement from which one might infer that Sir William Thomson thought that the noise produced upon the discharge of a condenser experimented with by him was due to a disruptive discharge. The article by Sir William Thomson, to which I presume Mr. Pope refers, expressly states the contrary. In an article entitled "Sound Produced by the Discharge of a Condenser," dated 1863 and published in *Electrostatics and Magnetism*, p. 236, Sir William Thomson states that he has had occasion frequently to discharge a condenser consisting of two parallel plates of metal separated by a space of air about .007 inch (which, it will be observed, is precisely the character of the Dolbear receiver), and charged to a difference of potential equal to that of about eight hundred Daniel's elements. He

then states that he remarked, at the instant of discharge, a sharp sound which seemed to come from the interior of the case containing the condenser, "and which struck me as resembling a sound I had repeatedly heard before, when the condenser had been overcharged and a spark passed across its air space. But I ascertained that this sound was distinctly audible when there was no spark within the condenser." He then describes some experiments which he made and which satisfied him that the discharge was not due to a spark. He states that he has since ascertained that suddenly charging the condenser out of one section of cable charged for the purpose produces the same sound within the condenser; also that it is produced by suddenly reversing the charge of the condenser. That would seem to establish the fact, first, that the sound was produced, and second, that it was not due to a disruptive discharge. Sir William Thomson came to the conclusion that it was due to a specific effect of the electrical charge on the thin plate of air between two plates of metal. I am not prepared to say that this is not a cause, but I am well satisfied that it is not the principal cause in the action of condensers which are under consideration in this case. So far as it is a cause it would exist in the Dolbear condenser as well as in that used by Sir William Thomson.

The Wright condenser is compared with the Dolbear condenser by Mr. Dolbear himself in his patent No. 235,745, April 5, 1881, and he states the distinction between his apparatus and the second apparatus of Wright mentioned in Ferguson. He does not suggest in stating this distinction that the sound in one is due to a spark, but asserts the difference to be that the vibrations caused in his own are what he calls mass vibrations, and in the other are chiefly what he calls molecular vibrations, though I understand the statements in his patent to admit that mass vibrations may also be produced in the Wright receiver.

Mr. Varley, in his description of his condenser, uses the following language: he first describes the employment of his condenser for the purpose of interrupting the line and preventing the passage of any electric current. "Impulses, however, passed through the condenser or the induction coil used, or both, and operated various forms of magneto receivers to produce musical notes corresponding

to the rate of interruption by the tuning fork transmitter." He then states that the condenser itself may be used as a receiver. "If the condenser be made in the following manner, the rapid charges and discharges will produce musical sounds: Sheets of tin-foil (for example, one foot square) are separated by one or more sheets of thin dry paper; the first, third, fifth, etc , sheets are joined together; the second, fourth, and sixth, etc., also joined together. The odd numbered sheets are connected to a binding screw or terminal, and the even numbered sheets to another terminal. Such a condenser, consisting of from twenty to thirty sheets, will be found to be much agitated, and to produce a loud note with five hundred alternations of current per second, if the potential be fifty to a hundred volts." Mr. Varley was probably more familiar with the use of condensers than any one else at that time, because their extensive uses in telegraphy are largely due to his inventions and improvements in them; and the language he employs in describing the cause of the sound when the sheets were agitated is appropriate to a vibration of the sheets and entirely inappropriate to a disruptive discharge from one to the other.

In the *Telegraphic Journal* for Aug. 1, 1877, p. 178, a description is given by Mr. Varley of the operation of this condenser when used as a receiving telephone. He there states that the sound is due to a movement of the air produced by the approach of the plates to each other caused by their attraction when charged and their recession when discharged. This is the same view which I understand him to have announced in his patent in similar phraseology.

The Journal of the Society of Telegraph Engineers, for 1877, p. 476, gives an account of a condenser receiver apparatus exhibited by Mr. Adams. He unhesitatingly rejects the hypothesis that sound was due to sparks, since he found it to occur when a film of talc, he says, was substituted for the paper ordinarily used to insulate the plates from each other, and after using the condenser and producing the sound he ascertained that no hole had been pierced through the talc. He produced the sound both with a battery and with a small induction coil, the discharge of which did not possess sufficient energy to send a spark through the slightest thickness of air. He thought that the sound was due to the action of the electricity on the in-

cluded air. In the discussion that followed the reading of this paper, Mr. Preece stated that he considered the vibrations to be due to the attractions of the plates for each other, as they were alternately charged and discharged, thus producing sound vibrations in the plates themselves.

S. P. Thompson, *Elementary Lessons in Electricity and Magnetism*, London, 1881, says: —

Page 227: "When a condenser is discharged a sound is often heard. This was noticed by Sir W. Thomson, in the case of air condensers; and Varley even constructed a telephone in which the rapid charge and discharge of a condenser gave rise to distinct tones."

Page 408: "Telephone receivers have also been invented by Varley and Dolbear, in which the attractions between the oppositely electrified armatures of a condenser is utilized in the production of sounds. The transmitter is placed in circuit with the primary wire of a small induction coil; the secondary wire of this coil is united through the line to the receiving condenser. In Dolbear's telephone the receiver consists merely of two thin metal discs, separated by a very thin air space, and respectively united to the two ends of the secondary coil. As the varying currents flow into and out of this condenser, the two discs attract one another more or less strongly, and thereby vibrations are set up, which correspond to the vibrations of the original sound."

I have also conducted a long series of experiments myself in connection with this point. Some of these were made as long ago as the early winter of 1880–1, others were made quite recently in connection with the present case. I have constructed receivers precisely similar to those described by Varley in his patent, where he gives detailed directions for their construction, and find, that on connecting their plates with the terminals of an induction coil, whose primary circuit is broken very rapidly several hundred times per second, the pitch of the note by the circuit breaker is perfectly reproduced, and this, whether I use a large coil capable of throwing a spark over an inch in length through the air, or a small one which could throw only a spark of about the twentieth of an inch in air. No piercing of the insulating plates occurred, and at the same time the plates of the condenser were vibrated very strongly, so that

their motion could be felt by the fingers, and this when a heavy board one half inch thick was placed on the top plate, and even when a very considerable weight was put on top of the board. Similar results occurred with a receiver constructed precisely as described by Dr. Wright in his article in the proceedings of the Scottish Society, on his substituting two plates of zinc separated by paper. I tested for these vibrations with Mr. Bell's "vibration explorer," and found that it gave sound with them. This instrument is described in *Nature* of July 28, 1881. The Wright instrument was also found to work clearly when, for the paper insulator, I substituted a sheet or board of vulcanite three eighths of an inch thick, and so broad as to prevent the possibility of any electricity creeping around the edges. Using the Dolbear receiver with an induction coil and circuit breaker a similar sound is heard, the character of the sound being much the same in all these three receivers. I also constructed a receiver similar to that made by Dr. Wright as described in Ferguson, consisting of two sheets of silvered paper placed back to back, and I found that the pitch of the circuit breaker was reproduced. I succeeded with this instrument in producing a disruptive discharge through the paper, after which the receiver became silent. In cases where I produced a disruptive discharge between the plates, the character of the sound was very different from what it was under the normal action of the receiver in its charge and discharge in the usual way. When for the silvered paper of this apparatus I substituted shellacked paper backed with tin-foil, which effectually prevented the passage of a spark, the sound persisted so long as the circuit breaker remained in operation.

From these experiments, which are only a few selected out of many that I have made during the period indicated, I conclude that a spark or disruptive discharge is not the cause of the sound produced in the Varley, nor in the Wright apparatus.

I have also repeated in a modified form the experiments of Sir William Thomson already referred to. I have found that charging a condenser by connecting its terminals suddenly with the opposite poles of a battery of eight hundred cells, arranged in series, gave a distinct click, and that upon discharging the condenser through its terminals in the usual way another distinct click was heard. The

hypothesis that the click is caused by a disruptive discharge, completely fails to explain its occurrence upon discharging the condenser, for previous to such discharge the difference of potential between two opposite plates is at its maximum, so that there is then the greatest tendency to discharge through the plate. On connecting the opposite plates of the condenser, the potential becomes the same in both, owing to a flow of electricity from the positive to the negative plate; and during the very short period in which discharge is taking place, the tendency to disruptive discharge through the plates is constantly diminishing. Yet the sound is substantially the same in this case as in the other, showing that the explanation suggested by Mr. Pope in his affidavit, but expressly rejected by Sir William Thomson, after experiment, is incorrect.

If I read correctly the affidavits of Mr. Dolbear and Mr. Pope, they do not deny absolutely that it was known previous to 1876, that sonorous vibratory motion of some sort in a plate could be produced by the electrical variations in the secondary circuit of a coil, but they state that mass vibrations, as they call them, were not known to be capable of production by varying the electric potential of two opposed plates, so as to produce sound. I do not know exactly what they mean by mass vibrations in this connection, nor what they mean by molecular vibrations.

Mr. Dolbear, in his book on *The Telephone*, p. 82, states distinctly that the difference which he attaches to the two phrases is a difference of more or less; and if the vibration is to be a sonorous vibration it must be so. The vibration of a body which is to produce sound must be a motion at the surface of that body in contact with the air, and what in the broadest term could be called mass vibrations is nothing more than that, though of course there may be differences in the range or extent of motion. There is such a thing known to physicists as molecular motion, that form of internal motion called heat, which does not cause any motion of the surface of the body perceptible as sound. There is undoubtedly a certain difference between the movement of a diaphragm supported at its edges and entirely free to move at its centre and the movement of a series of plates laid on each other where the motion of each is damped by contact with the others; but this is a difference, so far as the production of

sonorous vibrations are concerned, of extent and not of character. It is well known that the plate of a telephone will produce sonorous vibrations when pressed firmly against the soft part of the ear, or when damped by pressing a piece of india rubber against it. Indeed, Mr Dolbear has taken out a patent for pressing such a piece of rubber against the receiving plate of the telephone for the purpose of improving the sound.

Mr. Dolbear states in his patent of April 5, 1881, which I understand to be a patent on a receiver now in controversy, that, in his judgment, whatever vibrations occur in the Wright condenser are so damped by the plates as to be worthless for producing sounds. He does not anywhere refer to the Varley condenser, which must be equally well known to his advisers, because it was used in the Dowd suit in which Mr. Pope was expert witness for the defence. I suppose, however, that he would say the same of the Varley receiver that he does of the Wright; and I think that whatever applies to the one applies in every respect to the other. I do not understand him to say that he has ever actually tried to reproduce either sound or speech with either of these receivers. I have tried them many times for that purpose. I find that a small Wright condenser of his first form, made with zinc plates and enclosed in a case, similar to that used by Mr. Bell for his telephones, compares very favorably in its performance with one of the Dolbear receivers which I have already described, and that the larger condenser of Wright, constructed as directed in his article in the Transactions of the Royal Scottish Society, will readily reproduce speech. The Varley condenser, constructed as directed in Mr. Varley's patent already referred to, is also capable of reproducing speech, though less readily. I find that small instruments, constructed as described in Ferguson's *Electricity*, when placed in a suitable case will also reproduce articulate speech with tolerable distinctness and so as to be understood. All these condenser receivers have a somewhat peculiar quality of tone, similar to that obtained with the Dolbear, though somewhat different from that obtained with the magneto receivers. I find, moreover, that one of the Dolbear instruments will transmit speech when the spaces between the plates are filled up with layers of paraffined paper, and even when the plates are firmly

cemented together by pouring melted paraffine into the space between them and allowing it to cool, although in both these cases the freedom of the vibration of the plates is so much checked that the results are much inferior to those obtained when used as constructed by Mr. Dolbear. From these facts I conclude that the same cause is operative in the Varley, in the Wright and in the Dolbear apparatus. Without denying the possibility of greater complexity in certain of the phenomena in all those instruments than is implied in Prof. Dolbear's description of the operation of his own, I consider that there is no doubt both that the transverse vibrations of the plate are practically operative because much alike in all those instruments, and that the effect of such action was recognized before 1876; and that the condensers made before 1876, or directed to be made for the purpose of transforming the electrical variations into sound waves will to-day transform electrical undulations similar in form to the sound waves into corresponding sonorous vibrations, and thereby produce articulate speech. Of course I do not mean to assert that anybody produced articulate speech with either of these instruments before the date of Mr. Bell's patent.

Mr. Dolbear has departed from the precise construction of Wright and of Varley, and on the whole I think he has improved them. For their thin plates he has substituted a metal diaphragm, supported at its edges, which was shown and claimed in certain combinations of Mr. Bell's patent. He has added the sound box, which encloses the whole apparatus and gives the thin air space a central opening in front, which is described and claimed in Mr. Bell's second patent.

I have said that the vibration of the plates in the Wright, the Varley and the Dolbear was essentially the same. I do not consider, however, that precise identity in the particular manner of vibration is of importance to determine the identity of the Dolbear apparatus as a whole and the Bell apparatus as a whole, nor in determining the substantial identity of the Dolbear apparatus with the Wright or the Varley apparatus broadly as a means of producing sound. They both of them are condensers. They are charged and discharged as condensers are. The operation between one plate and the other — that is, the force exhibited between one plate and the other — is that force which is always present in condensers. The condenser as

a source of sound was by Mr. Varley substituted for a magneto receiver as an equivalent for it. So Dr. Wright substituted his condenser in the Reis apparatus for the magneto receiver used by Reis as a means of converting into sound electrical vibrations produced by the voice. They did not convert them into articulate sound because the vibrations were not of a character which could produce articulate speech.

Mr. Dolbear's patent, No. 239,742, dated April 5, 1881, describes his condenser receiver and one manner in which he connects it. It contains the statements which I have referred to, and at the request of the complainants' counsel I annex a copy of it to my affidavit.

I have already referred to one paragraph of it and stated what I have found to be the cause of vibrations in the Wright condenser. In this patent Mr. Dolbear disclaims what is shown in the English patent 4,934, of 1877, that is, the patent of Mr. Harrison. Fig. 15 of that patent describes a receiver which he says "consists of two or more plates or disks to act as condensers." They are connected with the line wire and the battery, or with the secondary coil. He states that they are to be placed at a very small distance apart, according to the degree of potential.

This acts upon the same principle as the Dolbear, in my judgment, and I have transmitted articulate words with it. It is inferior to the Dolbear in this, that both plates vibrate nearly equally, which probably confuses the sound, and they are not enclosed in the sound chamber described in Mr. Bell's second patent.

In the said patent Mr. Dolbear also disclaims all that is shown in the patent No. 2,396 of 1878. That is the patent of Mr. Thomas A. Edison. Mr. Edison shows in that two condenser receivers, one, Fig. 8, which is of a very special and peculiar form, introducing also some electrical phenomena not found in the apparatus as constructed by Mr. Dolbear. Fig. 32 shows another form of condenser in which the transmitter also consists of a condenser made of a plate vibrated by the voice in front of a mass of silver highly charged. Mr. Edison calls this second one an electrophorus instrument.

My attention has been called to the fact that the defendants have put in evidence on their part two questions and answers from the deposition given by me in the Dowd case. The first one of these

answers (34) is both true and complete. It is because no one had ever done what is there stated, and because, since Mr. Bell, Mr. Dolbear's apparatus does what is there stated, that Mr. Dolbear, unlike Mr. Bell's predecessors, is enabled to transmit speech; and that is one of the reasons why I consider that the Dolbear apparatus employs the Bell invention.

The second of those answers (35) does not apply completely to *all* cases without taking it in the sense and with the distinctions given in the following answer, 36, which the defendants did not introduce in evidence. Taking these answers together, I have stated what I believe to be the fact, and what is expressly stated in the first answer, that the connection between the transmitter and receiver must not be interrupted; and that the moving portion of the receiver must be constantly under the influence of, and guided by, the variations in the electric current caused by the motions in the transmitter, and that the electric circuit of the instrument must always present an uninterrupted path between the transmitter and receiver.

In my thirty-fifth answer I illustrated that by the case of a direct battery circuit. In my thirty-sixth answer I illustrated it by the case of conductors interposed between the transmitter and receiver but insulated from each other so that no current could pass from the one instrument to the other, but nevertheless placed in such relations to each other that an electric impulse would pass from one to the other. The case I referred to was where the induction coil was used. The case of a condenser is similar in this respect, and my thirty-sixth answer terminated with the statement of what was essential in the conductor in these words, "I think that the receiver is as constantly and fully under the influence of the transmitter as if the primary circuit current itself were transmitted," which is true of the Dolbear apparatus, and, if it were not, it would not transmit speech.

CHARLES R. CROSS.

STATE OF MASSACHUSETTS,
SUFFOLK, ss.

BOSTON, Feb. 11, 1882.

Subscribed and sworn to by the said Charles R. Cross, before me,

[SEAL] WM. W. KEITH, JR.,
Notary Public.

Extracts referred to in Affidavit of Prof. Cross.

Prof. Amos E. Dolbear, in *The Telephone*, Boston, 1877, says: —

Page 80: "When a membrane vibrates, its motion is generally perceptible to the eye; and it may have a great amplitude of motion, as in the case of the drum."

Page 82: "The vibration of a membrane and that of a solid differ chiefly in the amplitude of such vibration. The scratch of a pin at one end of a long log can be heard by an ear applied to the other end of the log; but every molecule in the log must move slightly; and there are all degrees of movement between that visible to the eye, which we call mass motion, and that called molecular, simply because we cannot measure the amplitude of the motion."

Page 106: "Dr. Wright found that a sound of considerable intensity could be obtained by passing the interrupted current through the primary wire of a small induction coil, and placing a conductor made of two sheets of silvered paper placed back to back in the secondary circuit. The silvered paper becomes rapidly charged, making a sound that can be heard over a large hall, and having the same pitch as the sending instrument."

Page 114: Prof. Dolbear describes Mr. Bell's magneto transmitter and receiver, and says: —

"This was the instrument exhibited at the Centennial Exposition, at Philadelphia, and concerning which Sir William Thomson said, on his return to England, 'This is the greatest by far of all the marvels of the electric telegraph.' . . . This was the first speaking telephone ever constructed, so far as the writer is aware; but it was not a practicable instrument: many sounds were not reproduced at all, and, according to the report of the judges at the Philadelphia Exposition, one needed to shout himself hoarse, in order that he might be heard at all."

Robert M. Ferguson, *Electricity*, London and Edinburgh, 1873. The concluding part of this author's description of the Reis telephone is as follows: —

Page 258: "Suppose a person to sing a note at the mouthpiece, which produces three hundred vibrations a second, the circuit is broken at the bladder three hundred times, and the iron wire tick-

ing at this rate gives out a note of the same pitch. The note is weak, and in quality resembles the sound of a toy trumpet. Dr. Wright uses a receiving apparatus of the following kind: The line current is made to pass through the primary coil of a small induction coil. In the secondary circuit he places two sheets of paper silvered on one side, back to back, so as to act as a condenser. Each current that comes from the sending apparatus produces a current in the secondary circuit, which charges and discharges the condenser, each discharge being accompanied by a sound like a sharp tap of a small hammer. The musical notes are rendered by these electric discharges, and are loud enough to be heard in a large hall."

Extract from English Patent of C. F. Varley, No. 1,044, *April* 8, 1870. — "There are various ways in which the wave signal receiving apparatus may be constructed, although that which I have already described I prefer; thus the condenser itself may be the receiving instrument.

"If the condenser be made in the following manner, the rapid charges and discharges will produce a musical sound: Sheets of tin-foil (for example, one foot square) are separated by one or more sheets of thin, dry paper. The first, third, fifth, etc. sheets are joined together; the second, fourth, sixth, etc. also joined together. The odd-numbered sheets are connected to a binding screw or terminal, and the even numbered sheets to another terminal. Such a condenser, consisting of from twenty to fifty sheets, will be found to be much agitated, and to produce a loud note with five hundred alternations of current per second, if the potential be fifty to one hundred volts.

"In constructing the dry-paper condensers, the following method seems to answer best: —

"Very thin, uniform paper is dipped in shellac varnish, coated on one side with gold leaf and then dried. The non-gilt surfaces of two sheets of paper are put together, so as to leave the gilt surfaces outside. The tin-foil plates are placed outside of these, and built up in the usual manner, connecting the first, third, fifth, seventh, etc. plates to one armature of the condenser, the second, fourth, sixth, eighth, etc. being joined to the other armature of the condenser."

Page 564: "I also claim the construction of electric telegraphs with, at the transmitting station, an instrument capable of originating in the line wire a succession of rapid and regular electric waves, and at the receiving station a condenser consisting of thin sheets capable of being agitated by such waves."

Royal Society of Arts, Transactions, 1860–64, vol. 6; Appendix, pp. 185–187. (185.)

The following communications were made: —

1. On the electrophone and some of its applications, by Horace Strethill Wright, M. D., F. R. C. P., with illustrations.

Dr. Wright having described to the society the mode proposed by the late Mr. Sturgeon for producing shocks by a voltaic pile charged with water only, and stated that Mr. Sturgeon had contemplated the application of the same method to the magneto-electric apparatus of Saxton and Clarke, stated that in 1842, he (Dr. Wright) had contemplated an induction coil of great intensity, to which he had applied the apparatus of Sturgeon, — a condenser of coated oil-skin. This he had afterwards changed for a condenser of coated mica. While employed on the above experiments, he had noticed the production of very loud sounds of certain forms of the apparatus, and had set himself to determine the best form for a sonorous condenser or electrophone for the production of audible sounds by such induction currents, and proceeded: —

"After many experiments I found that the form laid upon the table gave the best results. It consists of a plate of sheet zinc slightly curved, so that when resting on a hard wood table its ends vibrate freely. On this plate is laid one or more sheets of cartridge paper and on the cartridge paper a pile of three or four zinc plates, the upper plates being curved so as to vibrate freely when resting on the succeeding ones below. When the instrument is connected with a small coil, the poles of which afford a spark almost inaudible, and about one sixteenth of an inch in length, it becomes charged with each impulse of current, and discharges itself through the slightly conducting paper; each discharge being attended by a sonorous tap given out by the whole mass of metal thrown into vibration, and the rapid succession of taps producing a continuous musical tone, which, by using a powerful battery with a coil, may be deepened into a loud roar."

Figures and description found on page 186.

After some remarks by the president, Dr. Ferguson, and Mr. Thomson, and some additional observations by Dr. Wright, the communication was remitted to the same committee as on his two previous papers read at last meeting.

Extract from Patent of A. E. Dolbear, No. 239,742, *April* 5, 1881.

"I am aware of the apparatus mentioned as used by Dr. Wright in 'Ferguson's Electricity,' published by William and Robert Chambers, of London and Edinburgh, in 1867, pp. 258 and 259, in which two sheets of paper, silvered on one side, were placed back to back, and connected with the two ends of an induction coil, the primary circuit of which contained a Reis transmitter; and I disclaim that apparatus. My receiver differs from it in that the sounds transmitted are reproduced by the mass vibrations of one of the terminals; while in the Wright receiving apparatus the sound produced was mainly if not altogether due to molecular motion, and not to mass vibrations.

"Moreover, Wright's sheets of silvered paper were so arranged that each would damp any mass vibrations of the other; and in his apparatus any slight mass vibrations, even if not wholly damped, would be necessarily so irregular as to be worthless as a means of reproducing sounds. The fact, also, that the mass vibrations of each sheet damped those of the other sheet would make all the mass vibrations worthless for this purpose.

"I am also aware of English patents, No. 4,934 of 1877, and No. 2,396 of 1878, and disclaim all therein shown."

AFFIDAVIT OF GEORGES D'INFREVILLE IN REPLY.

I, Georges d'Infreville, having been duly sworn, on oath depose and say: My age is thirty-six years; I have been studying electricity and electrical apparatus, particularly telegraphy, for more than twenty years. For nearly ten years I have occupied myself as electrical engineer or consulting electrician in New York. I have been employed as electrician by the Atlantic and Pacific Telegraph Company, and am now in the service of the Western Union Telegraph Company as electrician. I have made an attentive study of electric speaking telephones for several years past. I am familiar with Mr. Bell's two patents, 174,465 and 186,787, and have had constructed in my shop and used telephones made in accordance therewith, while serving as expert for the National Bell Telephone Company. I know the Dolbear condenser receiver described in the affidavit of Mr. Davis and arranged as described by Mr. Buck, and have used such instruments.

I find in Mr. Dolbear's affidavit the following passage: —

"It is true that by Mr. Bell's method the air waves produced in speaking are caused to vibrate an instrument which holds the electric circuit under its control constantly, so that whatever movement of the diaphragm at any instant may be made will be converted into a corresponding electrical variation on the line wire, and I do the same."

I add to this the facts stated elsewhere in the defendants' affidavits, that both Mr. Bell and Mr. Dolbear employ these electrical variations when they have reached the receiving end of the line, to there produce sonorous vibrations in an elastic metal plate, and thus cause the listener at the receiving station to hear and understand a sound which is the same as that of the word uttered into the transmitter.

Upon the facts thus disclosed by the defendants' affidavit, I am of the opinion that the apparatus of Mr. Dolbear is substantially the same as the apparatus described in Mr. Bell's patent 174,465, referred to in his fifth claim, and transmits speech by and in accordance with the method disclosed in that patent, and referred to in that claim, which is as follows: —

"The method of and apparatus for transmitting vocal or other sounds telegraphically, as herein described, by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sounds, substantially as set forth."

I have read the defendants' affidavits. I think they contain some erroneous and some partial or incomplete statements of fact. But the matters of fact therein stated, if true, would not change my opinion, and correctly understood, they do not tend to contradict the opinion I have already expressed.

I will state some of the reasons which lead to this conclusion.

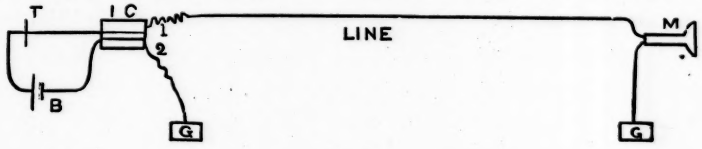


Fig. 1.

Fig. 1 is intended to represent a Bell speaking telephone apparatus such as is in ordinary use, and is, in my opinion, if correctly understood, substantially an apparatus described in said Bell patents and referred to in its fifth claim.

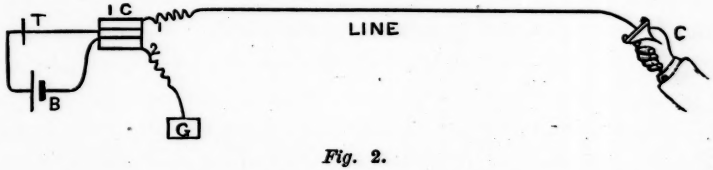


Fig. 2.

Fig. 2 is intended to show a Dolbear apparatus.

In each apparatus I find the following features in common: —

A primary circuit, included in which is a battery B, a variable-resistance transmitter T (of which the Edison is a well-known type), and the primary helix of an induction coil I C. This induction coil has a secondary helix, one terminal of which goes to earth at G, and the other terminal is connected to a line wire which goes to the distant station.

When speech is transmitted by this apparatus I find the operation

of these parts and the electrical phenomena which take place in them to be as follows: —

The voice vibrates the plate of the transmitter T. This varies the electrical resistance of the transmitter, but never interrupts the circuit. This varies the strength of the current in the primary helix of the induction coil. These variations produce corresponding currents in the secondary helix. One of said variations, considered by itself for instance, raises the potential of one terminal of the coil and lowers the potential of the other terminal; this causes a flow or current of electricity from either terminal along any electrical conductor which leads from it or joins it to a body of different potential, and this changes the electrical condition of the distant and every other part of that conductor; moreover, the voice uttering a word causes the plate of the transmitter to vibrate in accordance with the special "form" or character of the series of vibrations which constitute that word; this causes the resistance to vary in accordance with said character; this causes the variations in the primary conductor and helix to vary in accordance therewith; this causes the currents thereby induced in the secondary helix to correspond therewith in the character of their variation; this in turn causes the rises and falls of potential at the terminals to obey in their characteristics the same series of variation, and this compels the current due to the varying potential of the terminal the conductor is connected with to vary according to the same form or character.

This operation and these phenomena take place whenever a word is uttered near to the transmitter of either apparatus; and the transmission of that word to the receiving station so as to be there recognizable as the same word could not be accomplished in either apparatus unless this did so take place.

Each apparatus also has a receiver whose office it is to enable the electrical changes which are thus produced to reach the receiving station, to be there ultimately converted into sonorous air vibrations corresponding in form. In each, the receiver contains a metal plate which the said electrical changes cause to be attracted more or less strongly towards a neighboring and practically immovable body, and these motions of the plate correspond in form or character to

those electrical changes and produce sonorous vibrations of corresponding form or character in the air.

That the respective receivers should so act is necessary for the transmission of speech in each apparatus.

All this being as I have stated, I am of opinion that all other differences which I have been able to conceive of after reading the defendants' affidavits are immaterial as regards the embodiment in the Dolbear apparatus of the invention of Mr. Bell, defined in said fifth claim of the patent 174,465.

The currents which I have spoken of are not continuous currents, in the sense of a continued flow in one direction. Such currents are not necessary, and in ordinary practice are not used in any of the known forms of the speaking telephones. The currents which accomplish the transmission of speech in the speaking telephone are transient currents of excessively short duration, rapidly alternating in their direction, continually varying in their strength, but never ceasing to move while speech is being transmitted. The arrangement of Mr. Dolbear's conductors permits of such currents; they are present in all electrical parts of his apparatus and they are essential to its operation.

I do not indeed find that Mr. Bell's said fifth claim is limited to "currents"; but I do not find first, that the electrical changes which take place in Mr. Dolbear's apparatus are not prevented by anything in the arrangement of his conductors from being "electrical undulations similar in form to the vibrations of the air accompanying vocal or other sounds," and that in fact they are accomplished by and cannot take place without the intervention of currents.

The property of electricity which Mr. Dolbear makes use of in his receiver is a property which was well known before 1876; it had before that day been practically used in many testing instruments, and had been applied by Dr. Wright and by Mr. C. F. Varley to converting electrical variations into sound waves. The mode of operation of the condenser receiver of Wright described in Ferguson's *Electricity* and of the condenser receiver of Varley described in his English patent No. 1,044, of April 8, 1870, are the same in kind as that of the condenser receiver of Dolbear. The differences are changes of construction in the nature of improvements merely.

I believe firmly that the cause of the sound in those instruments of Wright and Varley was not disruptive discharges between the plates. The Wright condenser was of silvered paper; the Varley condenser was of foil. Varley states that he used five hundred alternations of current per second; Wright would, I infer, employ about the same number. If there were disruptive discharges, the instruments would be destroyed, and would cease to be condensers in a time much less than that required to perform the shortest experiment.

I have performed the following experiments: —

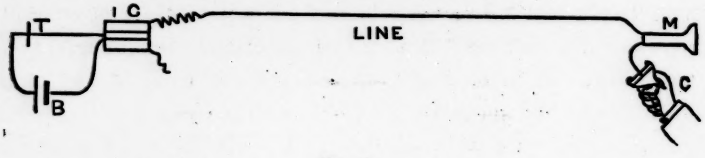


Fig. 3.

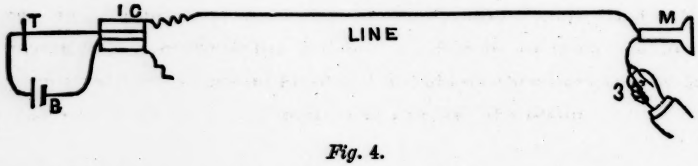


Fig. 4.

In Fig. 3 I inserted a Bell magnetic receiver by a loop in the Dolbear line conductor. Both the magneto and the Dolbear yielded articulate speech.

In Fig. 4 I left both ends of the circuit open; *i. e.*, using a single conductor not grounded with any body. I obtained articulate speech with a Bell magneto receiver thus connected, though it was feeble. Upon holding the farther terminal 3 of the magneto receiver in my hand the speech was much improved.

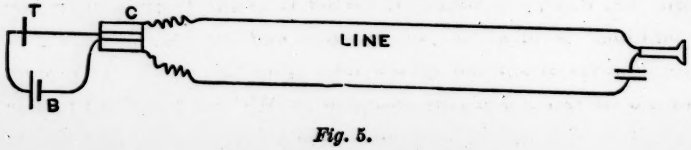


Fig. 5.

I then tried a Wright zinc plate condenser connected as shown in the diagram Fig. 5. I obtained articulate speech both in the magneto and in the Wright condenser. I then took out the Wright condenser and replaced it by a Varley condenser. I got articulate speech with this also.

I have examined the diagrams of the other experiments testified to by Mr. Cross in his affidavit in reply. I have not performed them because it has not been convenient for me so to do. I believe from my knowledge of electrical phenomena that the results would not be other than what he has stated.

GEORGES D'INFREVILLE.

Sworn to before me this tenth day of February, in the year 1882.

[SEAL] WM. ARNOUX, *Notary Public,*
Kings and New York Counties.

AFFIDAVIT OF PROF. ARTHUR W. WRIGHT, FOR COMPLAINANTS IN REPLY.

I reside in New Haven, Conn., and am professor of molecular physics in Yale College, which position I have held since 1872. Previously to that date I was professor of physics and chemistry in Williams College, Mass., from 1869 to 1872. My whole time since 1865 has been devoted to the study and teaching of physics and chemistry, and throughout the whole of this period I have given especial attention to the study of electricity as respects both the theory and its practical applications.

I am familiar with most of the forms of apparatus which have been devised for the electrical transmission of articulate speech, and have made experiments with many of them. The form of apparatus invented by Prof. A. Graham Bell, known as "the telephone," has been known to me from near the date of its invention; and I witnessed some of the earliest public exhibitions of it given by Mr. Bell in this city. I have also personally made many experiments with this apparatus, and well understand the details of its construction, the conditions for its successful operation, and the electrical principles involved in its action. I have read Mr. Bell's two patents, 174,465 and 186,787, and believe that I understand the inventions therein set forth and claimed. I shall confine my remarks particularly to the invention defined in claim five of patent 174,465.

The instrument devised by Mr. Dolbear for a telephonic receiver is well known to me; and I am acquainted with the general mechanical arrangements which constitute the telephonic apparatus described in the specifications of his patents Nos. 239,742 and 240,578. Without entering into an extended comparison, it may be sufficient to consider the points in which, according to the claims made for the Dolbear telephonic apparatus, the two forms of apparatus are alleged to differ in such a way as to render the latter and its operation an independent and novel method for the electrical transmission of articulate speech.

As I understand the statements made in the affidavits for the defendants, no claim of such novelty is made for any parts of the Dolbear apparatus other than the receiver, or for any details in the operation of the system except such modification of the electrical conditions occurring upon the line as are alleged to result from the substitution of this receiver for the receiving instrument employed upon lines which they say are operated under Bell's patents; that, in short, the Dolbear telephonic apparatus as a whole is substantially identical with the Bell apparatus as a whole, except in the substitution of a part known as the Dolbear receiver for a corresponding part, namely, the magneto-receiver of Bell, and as regards such changes of the electrical conductors as in ordinary practice accompany and they say necessarily accompany the selection and use of one receiver or the other.

It is claimed by the defendants that the action of electricity in the two forms of apparatus is specifically different; that in the Dolbear apparatus it is employed in the form of a static charge, while in what they call Bell's system it is dynamical electricity which is used to produce the effects desired. So far as the direct action of electricity in moving the vibrating plates is concerned, a difference in the two systems undoubtedly exists; but here the distinction stops. In both cases the electricity which passes over the wire to the receivers is subject to incessant variations.

According to the fifth claim of Mr. Bell's patent 174,465, he transmits speech by causing those electrical variations to conform in their character to the changes in the acoustic undulations which are set up in the production of sound or articulate speech; and Mr. Dolbear's apparatus causes all the electrical variations which take place in it to conform in their character to the same changes. If this conformity did not exist in the operation of the Dolbear apparatus, it would not transmit speech. In the apparatus of both, these variations of electricity upon the line are true currents of limited duration; and this is necessarily true of all speaking telephone apparatus whatever.

When a long insulated wire is connected at one end with one pole of a voltaic battery, the other pole of which is grounded, a rush of electricity into the wire takes place until the wire has become charged to the tension of the battery. On breaking the connection

with the latter and putting to ground that end of the wire which was first connected with the battery, a rush of electricity in the opposite direction takes place and the wire is discharged. These effects can readily be detected by means of a galvanometer, through which the electricity passes as it enters and leaves the wire. When the latter is short and well insulated, the duration of the passage of the charge is very brief; on the other hand, it is increased if the wire be made very long and of high resistance, or if the remote end is connected with a conducting body of some capacity. If the wire is touched to the collector of an electricial machine, or any conductor having a charge of statical electricity, similar effects follow. The charge of statical electricity, as it moves over the wire, when a path is provided for it to move over, becomes dynamical electricity, and is a true current of a transient character. Now if in experiments upon discharges of statical electricity the remote end of the wire, instead of being free, is connected to an insulated conductor, the electricity passes into the latter, and the quantity which thus passes is dependent upon the capacity of such conductor. The movement in the wire is of the same nature as when the latter is connected with the earth. The fact that the wire which conveys the electricity to the Dolbear receiver is not connected through the latter to the earth makes no material difference in the electrical condition of the line wire as compared with that existing under what the defendants call the Bell system, except as regards the quantity of electricity passing, inasmuch as the metal plate of the receiver has sufficient capacity to admit of an electric accumulation which is substantially sufficient for telephonic work. In both cases the currents are transient, in both they are essentially the same in nature and must follow the same laws.

It is claimed by Mr. Dolbear that the form of his receiver, by making a complete break in the line wire, while in what he calls the Bell system the latter is continuous through the receiver to the ground, introduces such a difference of condition that the electricity passing in the former case does not obey the law of Ohm, while in the Bell system it must and does follow that law. This claim involves an error as to the application of Ohm's law, in respect to which an important point has been overlooked. The law commonly

known as Ohm's, which is the mathematical expression of the fact that the current strength varies directly as the electro-motive force and inversely as the resistance, is only true for a current which has attained what was called by Ohm (*Die Galvanische Kette matematisch bearbeite*, Berlin, 1827. Translation in Taylor's Scientific Memoirs, vol. 2, Art. XIII), *the permanent state:* that is, which passes steadily, without interruption or variation. When the resistance of the circuit is increased the current strength diminishes, and when the resistance becomes infinite, as in the case of an open circuit, such a current ceases to exist; and this constitutes merely a limiting case under the same general law above quoted. But steady currents are not and, for obvious reasons, cannot be employed in the transmission of speech.

For the varying and transient currents, or electrical undulations, which are employed equally in the Bell telephone and the Dolbear telephone, the simple law above quoted does not apply. Such currents are shown by Ohm to follow a far more complicated law, which, however, must hold equally well for all forms of apparatus using undulatory currents of the same transient character.

I do not mean to say that increase of electro-motive force does not increase the current, or that increase of resistance does not diminish the current, on a telephone line. What I mean is, that since we here have to deal with currents not in the "permanent state" but in the "variable state," the elements of change and time enter as such important factors that Ohm's law, which expresses the whole truth as to the one kind of current, does not express the whole truth as to the other. In this respect the currents in what the defendants call the Bell system are found in the variable state as much and to the same extent as they are in what they call the Dolbear system. The asserted discrimination between the two forms of apparatus, as respects the application of Ohm's law to the currents on the line wires, has no significance for steady currents, which are useless for telephonic purposes; and in the case of the undulatory currents used it does not exist.

It is further claimed on behalf of the Dolbear apparatus, that, as the line is broken by the interposition of the receiver, while in what the defendants call the Bell system the line wire is continuous with

that of the receiver coil, and through this is connected with the earth, that the former employs an open circuit, and the latter a closed circuit, and can only operate upon such a circuit; and it is contended that this constitutes a material difference. That this distinction can justly be made as respects the ordinary voltaic currents is obviously true, but as respects the transient currents, or electrical undulations, which alone are operative in the reproduction of articulate speech, the conditions are totally distinct. A new and essential factor in the problem enters, in the fact of induction. When the electrical status of a conducting body is made to vary, corresponding variations are produced in a neighboring conductor by induction, either electro-static or electro-dynamic, or both, according to the form and capacity of the second conductor and its relation to, or connection with, other connecting bodies or the earth. In the Dolbear receiver, it may he admitted that the varying potential of the plate attached to the line wire causes variations in the potential of the second plate, resulting in attraction. But this is not all. If this second plate is connected by a wire to the ground, to a second receiver of the same kind by an insulated conductor, or to one pole of a Bell receiver, the variation of potential in the first plate of the first receiver aforesaid causes, by induction, a passage of electricity in the connecting wire to or from the second plate of that receiver, thus giving rise to electrical undulations or transient currents in this wire.

If a series of undulations proceed from the transmitter over the line wire, a similar series of undulations is produced in the wire issuing from the second plate of the Dolbear receiver above mentioned; and the separate impulses or undulations of this second series will necessarily bear the same relation to one another, as respects time, phase, and duration, as do those upon the line wire to each other. If the undulations in the first wire are of such a character that, acting upon a suitable receiver, they will produce intelligible speech, those in the second wire are equally fitted to bring about this result, and will do it. This conclusion is clearly indicated by theory; and I know it to be true from many experiments, of which the following may serve as examples: In these experiments, the transmitting apparatus was placed in a distant room, separated

by three doors from the place where the observations were made, so that no sound could be heard directly. Two independent circuits between the rooms were used, one being of the ordinary office wire, insulated by a double coating of paraffined cotton thread, the other a somewhat larger wire insulated by a very heavy coating of kerite. Both circuits were well insulated. Usually, one pole of the induction coil was grounded by means of a wire passing to a gas pipe, and the other connected to one of wires above mentioned, which represented the line wire, and is so designated in the following paragraphs: —

Occasionally, both wires were used, so as to complete a return circuit. A separate circuit conveyed the current from a battery to the primary wire of the coil and the transmitter.

First. A small induction coil provided with a vibrating circuit breaker being used, one of the poles of its secondary coil was joined to the line wire, and the latter at the receiving end to one of the terminals of a Bell telephone M, the other terminal of which was grounded. The undulations produced in the wire by the motion of the break-piece caused the telephone to give forth a loud sound of the same pitch as that produced by the break-piece itself when vibrating. The arrangement of circuits employed is illustrated by the diagram, Fig. 1, the transmitter T of which, in the primary circuit of the induction coil I C, was replaced by the vibratory circuit-breaker of the coil.

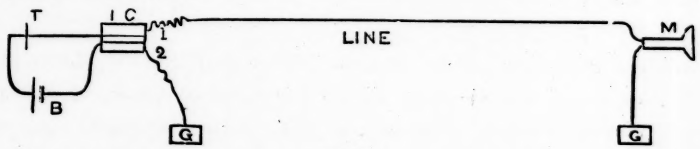


Fig 1.

I then varied the arrangement by the employment of two Æpinus condensers, composed of thick brass plates without the glass panes; that is, with only an air space intervening. The plates were circular and in the larger apparatus were six and three quarters inches in diameter; those of the other condenser were three and one quarter inches in diameter. During the experiments the condensers were separated by a distance of from six to eight feet; the line wire was connected to the lower plate of the large condenser, while the wire from the earth was united to the corresponding plate of the smaller.

To the other plates, which could be raised or lowered upon their supports, were fastened the conducting wires of the telephone, which was thus inserted in a wire conductor between them. When the coil was set in operation, sound was heard from the telephone as before, and was still di-tinctly audible when the parts of the large condenser were separated by a distance of more than one foot, and those of the smaller four inches or more. The diagram Fig. 2 shows the arrangement of conductors employed.

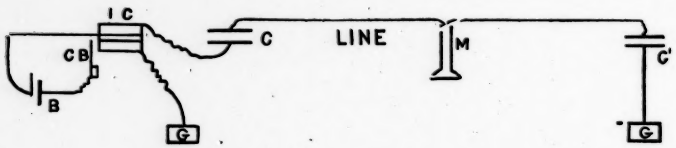
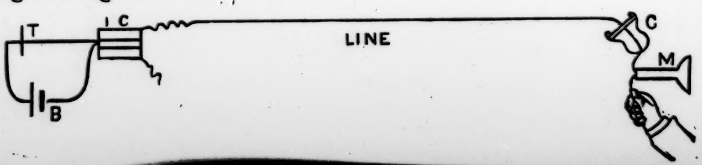


Fig. 2.

The pitch and timbre of the sound were the same as when the telephone was inserted directly in the circuit of the induction coil, the only essential difference being in the intensity, which varied in a marked degree with the distance between the condenser plates. This shows that the undulations set up in the telephone wire by induction were of the same character as those in the wire from the coil, though connection between them was prevented by an air space of several inches.

Second. A carbon transmitter being placed in the primary circuit of a similar but larger coil, which was placed in the distant room, and the same arrangement being used as above described, words spoken into the transmittter were distinctly heard and perfectly understood in the telephone, while the condenser plates were separated, though the distance between them was much smaller than before.

Third. I then arranged instruments and conductors as shown in diagram Fig. 3.



The wire from the coil, that is, the line wire, being connected to one plate of a Dolbear receiver, the second plate of the latter was connected with one terminal of a Bell telephone, the other terminal of which was grounded, or simply touched with the finger. Here the Dolbear receiver played the same part as the large condenser in the preceding experiment. Speech was distinctly and easily heard from both receivers.

Fourth. I then arranged conductors and instruments as shown in diagram No. 4.

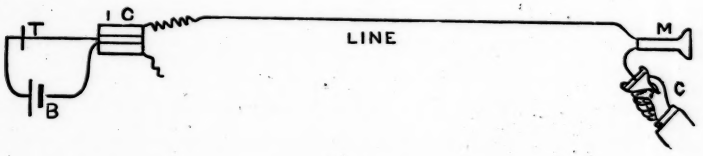


Fig. 4.

The positions of the two instruments were interchanged, the Bell telephone being now inserted in the line, the Dolbear receiver in the ground circuit of the former; the result was the same as before, except that the articulation of the Dolbear receiver was apparently clearer than when used alone upon the line.

Fifth. I then adopted the arrangement of conductors and instruments shown in diagram No. 5.

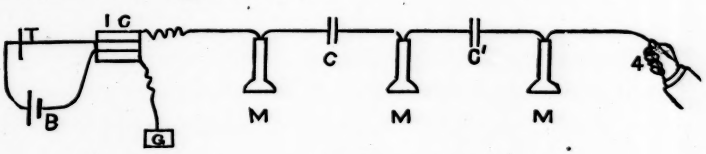


Fig. 5.

Three Bell and two Dolbear receivers were inserted into the line in series, and so that the Dolbear instruments were between the Bell receivers, the last one of the latter being arranged so that its terminal (4) could be grounded or left free. When words were pronounced at the transmitter they were reproduced in all of the receiving instruments; and this was true even when the terminal wire (4) was left free or insulated. When it was touched with the finger or otherwise grounded, the same effects were observed; and the sound,

otherwise unchanged in character, was simply made more intense, especially from the last telephone of the series, as was to be expected.

The purport of these results is obvious. They prove conclusively that the break in the line conductor made by the Dolbear receiver, so far from presenting a bar to the transmission of the electrical undulations, permits them to pass with the utmost facility, merely serving slightly to diminish their intensity. This diminution is the necessary consequence of the fact that the charge produced through a dielectric is always less than the inducing charge, and depends also in part upon the greater or less capacity of the body in which the induction takes place. The air space has then merely an effect analogous to that of a resistance introduced into the line; and several such breaks may be introduced without preventing the reception and distinct understanding of speech from telephonic receivers placed beyond them. To state this result in other words, the Dolbear circuit, which for continuous currents is an open circuit and permits no passage of electricity, freely transmits through all its parts electrical undulations caused by the action of the transmitter, substantially unchanged in all those particulars which are essential to the reproduction of speech, as would a closed circuit with somewhat increased resistance. Here also the distinction between what the defendants' affidavits call an *open* and what they call a closed circuit, as to the effects produced, falls to the ground.

Further, these experiments have an important bearing upon another claim made for the Dolbear instruments, which is, that the electric variations which reproduce speech in this receiver are incapable of working the Bell receiver, and *vice versa*, that the currents which cause speech in the latter apparatus cannot work the Dolbear receiver, regard being had of course, not simply to the direct action upon the vibrating plates, but to the whole operation of the electrical variations existing. It is abundantly proved by the experiments that the currents which are efficient in one case are also efficient in the other.

The receiving apparatus. I understand Mr. Dolbear in his affidavit to make the claim that he was the first person to discover the fact that variations in the electrical potential of a metal plate, as for instance the plate of a conductor, could be used to set this plate into vibration in [illegible] produce

articulate speech. Waiving for the present any discussion of the priority in the invention of the particular mechanical arrangement of the receiver, the question as to the novelty of this application of electricity may be determined by an examination of the history of observations upon the sound emitted by condensers, and of the use of condensers of special construction for the express purpose of producing sound. There is involved in this also the question whether the attraction caused by the statical charge is the sole and sufficient cause of the vibration and the consequent production of sound.

In a letter to Prof. Tait, dated Oct. 10, 1863, reprinted in the volume entitled *Papers on Electro-Statics and Magnetism*, 1872, p. 236, Sir Wm. Thomson states that he had remarked a sharp sound on discharging an air condenser, that he had satisfied himself that no spark discharge across the air space took place, both by the entire absence of luminous phenomena and by the fact that the whole discharge "took place fairly through the 2,000 yards of fine wire constituting the galvanometer coil." He further says: "I have since ascertained that suddenly discharging the condenser out of one of the specimens of cable charged for the purpose produces the same sound within the condenser; also, that it is produced by suddenly reversing the charge of the condenser." He states the following conclusion: —

"Thus it is distinctly proved that a plate of air emits a sound on being suddenly subjected to electric force or on experiencing a sudden change of electric force through it."

In the year 1870, Mr. C. F. Varley obtained a patent (English patent, No. 1,044) for a telegraphic apparatus in which the sound emitted by a condenser is utilized. In this system the current from a battery traverses the primary wire of an induction coil. The induction currents generated in the secondary wire of the coil are conveyed by a wire from one of its poles (the other being grounded) to one plate or set of plates of a condenser. The other plate of the condenser is connected to a line wire. At the other end, the line wire is connected to one terminal of a condenser at the receiving station, the remoter terminal of this condenser being connected to the ground.

The following diagram shows the arrangement of conductors employed by Varley.

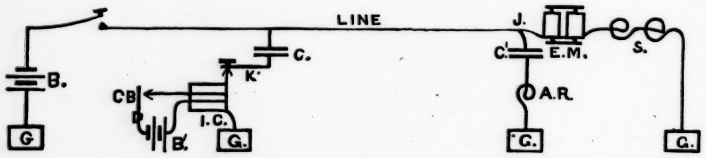


Fig. 6.

K was the key of a Morse transmitter at the sending station; S was a Morse sounder or other equivalent receiver at the receiving station; C and C′ were two condensers; C B was a vibrating circuit breaker at the transmitting station; K′ was a Morse key; A R was an acoustic receiver; E M was a large and sluggish electro magnet. Mr. Varley's statement of the operation was, that the signals sent by the Morse key K would work the Morse receiver S, but were not sufficiently sharp and rapid to produce effects on or through the condensers. On the other hand, the rapid and sharp "wave signals" sent by the harmonic transmitter C B, which broke the circuit several hundred times a second, would pass through the condenser C by induction, would reach the point J, would not be able to effectively pass the sluggish electro-magnet E M, but would pass to the condenser C′, then inductively affect or pass through that instrument to the ground, operating the acoustic magnet receiver on its way.

Confining our attention to what Mr. Varley calls the "wave signals," which are those sent from the induction coil I C, and which operate the receiving condenser C′, or the receiver A R, we find that in this apparatus the electrical impulses produced by induction in the secondary wire of the coil alone pass over the line wire, as no part of the battery current can enter it. Mr. Varley proposes to utilize these currents to work acoustic magnetic receivers of various forms, for which they are well suited; he also suggests the use of the condensers themselves for producing sound, as the following extract from his patent above mentioned may show: —

"The first or communicating station produces in its condenser rapid charges and discharges. These add to and take from the line

a number of small electric impulses without affecting the mean magnetizing power of the currents through the line; these impulses charge and discharge the second condenser at the other end.

"These undulations in the second condenser can be utilized in the following manner: —

"*First.* If the condenser be made of paper and metal foil, the rapid charges and discharges produce a musical sound.

"*Second.* If those rapid alterations be made to pass round a helix containing an iron rod, a musical sound is produced," etc.

He further describes the construction of the condenser, which is made of alternate sheets of tin foil and thin dry paper, and remarks, "Such a condenser, consisting of from 20 to 50 sheets, will be found to be much agitated and to produce a loud note with 500 alternations of current per second, if the potential be 50 to 100 volts."

Mr. Varley subsequently employed a similar arrangement as a musical telephone, which was publicly exhibited in London, in the summer of 1877. See *Telegraph Journal and Electrical Review*, Vol. 5, 1877, pp. 176, 178.

Similar experiments by MM. Pollard and Garnier are described by Count du Moncel, in a volume entitled *Le Téléphone*, Paris, 1878, from which the following is extracted (pp. 122, 123): "Si on place dans le circuit induit d'une bobine d'induction reliée à un téléphone, un condensateur de grande surface et que l'on éloigne assez le contact de plombagine de la lame vibrante pour ne la toucher que momentanément à chaque vibration, on ne reçoit plus naturellement les articulations des sons, mais seulement les notes d'un air que l'on chante devant la plaque du transmitteur; seulement le courant inducteur ayant des interruptions brusques, engendre des courants très-intense, et, suivant, MM. Pollard et Garnier, on entend dans tout un appartement l'air chanté, mais avec un timbre particulier qui dépend de la construction du téléphone et du condensateur."

This is translated as follows: "If we insert in the induced [*i. e.* secondary] circuit of an induction coil connected with a telephone, a condenser of large surface, and withdraw the carbon from the vibrating plate so far that it touches it only momentarily at each

vibration, we naturally no longer receive the articulation of the sounds, but simply the notes of an air which is sung before the plates of the transmitter; but as the interruptions of the inducing current are sudden, it produces very intense currents, and, according to MM. Pollard and Garnier, one hears the air which is sung throughout the whole room, but with a peculiar quality which depends upon the construction of the telephone and the condenser."

Previously to 1867, Dr. Wright of Edinburgh showed (*Transactions of the Royal Scottish Society of Arts*, 1860–1864, vol. 6; Appendix, pp. 185–187. *Ferguson on Electricity*, 1867) that a condenser formed of two sheets of paper silvered or covered with thin metal foil placed back to back, or of thin plates of zinc slightly curved and separated by sheets of insulating paper, would produce loud sounds when connected with the secondary wire of an induction coil. These condensers reproduce musical sounds, and both forms are suited to reproduce articulate speech so that it can be readily understood, and will do so, as I know from repeated experiments with condensers of the same construction. Either form inserted in circuit with a Dolbear receiver, or in place of such receiver, with any arrangement of conductors which will produce speech in the latter, will give forth the words spoken into the transmitter with a loud tone and distinct articulation.

In an article in *La Lumière Electrique*, 3me Année, No. 5, March 1, 1880, p. 90, is found a description of certain forms of speaking condenser, which shows that this instrument and its function of reproducing speech were well known at that date, as appears by the following extract: —

"MM. Herz, Dunand et Coulon en ont construit dans des conditions differents et parfaitment isolés. Ils en ont fait avec du papier dioptique, du papier paraffiné, et même en substituant au papier du vernis à la gomme laque ou du vernis noir qu'on répandait sur chacun des faces des feuilles d'étain et qu'on séparait de plus par du papier, et tous ces condensateurs parlaient fort bien. M. Coulon a demontré d'ailleurs dans un travail très-intérressant sur les condensateurs que nous avons publié dans ce journal (Année 187?) *que les condensateurs dont les feuilles de papier étaient percés de petites trous produits par des étincelles, et qui se trouvaient en conséquence*

mal isolés, devanaient muets, alors qu'étant percés de trous non carbonisés comme des trous d'aiguille, ils reprodui-aient les sons. Toutefois il a reconnu que *c'étaient quand l'isolation était la meilleure possible que la répetition des sous était la plus énergique.*"

This may be translated as follows: "Messrs Herz, Dunand and Coulon have constructed these [i. e., *condensers*] under conditions which were different and perfectly independent. They have made them of transparent paper [*tracing paper?*], of paraffine paper, and even in substituting for paper shellac varnish or black varnish which was spread upon each of the faces of the sheets of tin, which were further separated by paper, and all these conductors produced speech very well. Further, M. Coulon has shown in a very interesting article which we published in this journal (in 1879) that condensers in which the paper sheets had been pierced with small holes produced by sparks, and which consequently were not well insulated, became silent, although when the perforations were small like needle pricks and the paper not carbonized, they reproduced sounds. However, he has always found that it was only when the insulation was as perfect as possible that the reproduction of sounds was most energetic."

A little later, M. Herz applied the speaking condenser in a system of telephony developed by him, and patented in France toward the end of 1879 or early in 1880. In an article upon this system by Du Moncel, *La Lumière Electrique*, Année 3, No. 6, Feb. 5, 1881, p. 100, the author says: "Comme récepteur, on a employé les téléphones magnetiques, mais aussi le *condensateur parlant*, et à ce sujet il ne sera pas sans intèrêt de rapporter les différentes expériences qui ont été faites depuis près d'une année avec cet intéressant instrument."

"Le 23 juin, 1880, M. Herz m'ayant prié d'assister aux expériences qu'il faisait boulevard Saint Marcel, attira mon attention sur ce fait qu'un condensateur de petite dimension comme en on trouve chez tous les constructeurs a Paris, pouvait, dans certains conditions, réproduire la parole. Je pus effectivement constater ce fait et je'en fus trés etonne."

Translated, this is as follows: "As receiver the magnetic telephone has been employed, but also the *speaking condenser*, and it

will not be without interest in reference to this subject to recall the various experiments which have been made, within a period of nearly a year, with this interesting instrument."

"On the 23d of June, 1880, M. Herz, having requested me to be present at experiments which he was making in the boulevard Saint Marcel, drew my attention to this fact, that a condenser of small size, such as may be obtained from any of the instrument makers in Paris, could, under certain conditions, reproduce speech. I was able actually to confirm this fact, and was greatly astonished at it."

In the same article, Du Moncel further says, p. 101: "Avec ce système on est parvenue, comme nous l'avions annoncé, à entendre la parole, du moins quelques phrases détachés, a une distance énorme, 1,100 kilomètres. On a reconnu qu'avec trois é'éments Leclanché on pouvait correspondre aisément sur les lignes de Paris, Tours, Poitiers, etc., même quand les lignes voisines étaient en pleine activité." Again p. 102: "Le condensateur parlant a pu être très bien entendu entre Paris et Orleans et entre Paris et Tours."

This translated is as follows: "With this system they have succeeded, as we have announced, in understanding speech, at least some detached phrases, at an enormous distance, 1,100 kilometres. It has been found that with three Leclanché elements one could converse easily upon the lines of Paris, Tours, Poitiers, etc., even when the adjoining lines were in full activity." Again, p. 102: "The speaking condenser has been very well understood between Paris and Orleans and between Paris and Tours."

This system was also patented in England in July and August, 1880. See *Telegraphic Journal and Electrical Review*, vol. 10, Oct. 1, 1880, p. 336.

In the volume entitled *The Speaking Telegraph, Talking Phonograph and other Novelties*, by George B. Prescott, New York, 1878, will be found, pp. 231, 232, a description of a form of telephonic apparatus attributed to Edison in which the attraction of a diaphragm by varying charges of statical electricity is employed. Edison uses an electrophorus disk as the source of the charge, which is varied by the to-and-fro motion of a vibrating metal disk placed in front of and very near to it. The receiver is of exactly the same construction, and its operation depends upon the vibratory motion communicated

to the diaphragm by the variations of the charge produced by the electrical undulations sent over the line from the transmitter. In his own account, quoted in Mr. Prescott's book, he says of this form of the instrument: "The vibrations of the transmitting diaphragm cause a disturbance of the charge at both ends of the line, and thus give rise to faint sounds. Perfect insulation, however, is necessary, and either apparatus can be used both for transmitting and receiving, but the results are necessarily very weak.

"Another form of electro-static telephone is shown in Fig. 3 (*omitted here*). In this arrangement Deluc piles of some 20,000 disks each are continued in glass tubes A and B, and conveniently mounted on glass, wood or metal stands. The diaphragms, which are in electrical connection with the earth, are also placed opposite to one pole of each of the piles, while the opposite poles are joined together by the line conductor. Any vibration of either diaphragm is thus capable of disturbing the electrical condition of the neighboring disks, the same as in the electrophorus telephones; and consequently the vibrations when produced by the voice in one instrument will give rise to corresponding electrical changes in the other, and thereby reproduce in it what has been spoken into the mouthpiece of the former." So far as the action of the varying electrical charge upon the diaphragm is concerned, this form of telephone is substantially identical with the receiver No. 3 described by Mr. Dolbear in his patent No 240,578, p. 2, lines 24 to 33, in which, for the metallic back plate, is substituted a plate of hard rubber, which is to be electrified by the friction of a felt pad turned by the hand.

The references and extracts given in the preceding paragraphs clearly show that the production of sound by the charging or discharging of a condenser, or by suddenly reversing the charge, was familiarly known long before the date of Dolbear's patent; that the condenser had been used for the production of musical sounds as by Mr. Varley and Dr. Wright as early as 1870 or earlier; that in 1880 it was well known from widely disseminated publications that the condenser could be used as a telephonic receiver for the reproduction of articulate speech; that in the same year a complete telephonic system, that of M. Herz, in which the speaking condenser was an essential part, was made the subject of patents in France and

England, and was proved by successful experiments to be practicable; and further, that as early as 1878, Edison had proposed, and published an account of, a receiver dependent upon the same electrical action, and in principle and mechanical arrangement essentially the same as the Dolbear receiver.

It is asserted by Mr. Dolbear in his affidavit that the action of electricity in producing sound in his receiver is due to electro-static attraction, while in the speaking condenser employed by other experimenters the sound was produced by disruptive charges through the insulating material of the condenser.

The same assertion is also made in the affidavit of Mr. Pope for the defendants. That attraction is a consequence of the charge produced upon the plates of the receiver is unquestionably true; and it is equally true that if these attractions take place in the proper order, they may cause the plates to vibrate in such a manner as to reproduce speech. This attraction will necessarily be produced, however, in any form of condenser composed of metal sheets or plates separated by insulating material, whether the latter be simply air, or consist of solid substances, like paper saturated with shellac, paraffine or the like, when subject to varying charges of electricity; and the attraction of the sheets of metal, if sudden, must cause not only themselves to vibrate, but also the insulating material itself, in short, the whole mass of the condenser. These vibrations, if sufficiently intense, must give rise to audible sounds. But there is another efficient cause for the sound in the direct action of electricity upon the insulating material of the condenser itself, whether this be air alone or some solid substance. The remark of Sir William Thomson, already quoted, attributes the sound produced in the condenser used in his experiments to the air between the plates. He says: "It is distinctly proved that a plate of air emits a sound on being suddenly subjected to electric force, or on experiencing a sudden charge of electric force through it. This seems a most natural result when viewed in connection with the new theory of Faraday, in his series regarding the part played by air or other dielectric in manifestations of electric force." This language cannot be interpreted as implying that anything in the nature of a disruptive discharge took place; and he expressly states that nothing of the kind occurs.

The production of sound in the charge and discharge of a Leyden battery had previously been observed by Knochenhauer in 1853 (*Pogg. Ann.*, vol. 90, p. 189, 1853), and was explained by De La Rive (*Archiv. Sc. Phys.*, t. 25, p. 64, 1 54) as being a consequence of the electric polarization of the glass, in accordance with the theory proposed by Faraday. That the dimensions of glass under the action of electric charges undergo an alteration has long been known, having been observed by the Abbe Fontana in the case of a Leyden jar, more than a century ago. This observation is quoted by Righi in the memoir mentioned below, from a letter of Volta, dated Jan. 27, 1776. In 1878, Duter investigated the character of this change in glass, and concluded that it was due to a specific action of electricity and was not to be explained as the result of an increase of temperature. (*Compt. Rend. de l'Acad. Sc.*, 87, pp. 828, 960, 1036, 1878.) This was confirmed by Righi, *Compt. Rend.*, t. 88, p. 1262, 1879, who further determined the fact that the total dilatation in the case of glass could be considered as made up of two parts, one of which appeared and disappeared instantaneously with the charge and discharge, while the other persisted for some time. He expressly attributed the action of Varley's singing condenser to the effect of these instantaneous changes of volume produced by the sudden electric variations in the insulating material. In an extended memoir, published in 1880, in *Wiedemann's Ann. der. Phys. u Chem.*, Quincke showed that, besides glass, mica, quartz, india-rubber, carbon disulphide, water, alcohol, and a number of other substances exhibited like effects on being subjected to dielectric polarization.

Finally, Lippmann, in a discussion of some experiments made by Boltzmann in 1875, established the fact that air and other gases likewise experience a change of volume on being submitted to dielectric polarization, the change in this case being a contraction. *Journal de Physique*, t. 10, No. 117, 1881, pp. 384–389.

The mechanical effect of these changes of volume in the insulating material of the condenser in producing vibration would depend upon the intensity of the charge and the suddenness of its variations. When these are rhythmical or conformed to the undulatory motion produced by articulate speech, it is a natural and necessary consequence that, if sufficiently energetic, they produce musical tones or intelligible

speech. In all forms of condensers then the production of sound must involve the operation of both the causes above mentioned, and the preponderance of the one or the other will depend upon the form of the particular instrument employed as a receiver. That it is not due to disruptive discharge is evident from the observations of Sir W. Thomson and Coulon, already quoted. Such a discharge destroys the condenser and incapacitates it for producing sound.

If the space between the plates of a Dolbear receiver be filled with insulating paper or other dielectric material, it will still produce sound and reproduce speech, though somewhat diminished in intensity, since the plates, by being more or less rigidly confined, are placed in conditions less favorable to energetic vibration. The Dolbear receiver in its essentials is simply an air condenser, and owes its power to reproduce speech to the same causes as other speaking condensers.

Whether Mr. Dolbear was the first to apply the particular mechanical arrangement of the condenser described in the specifications of his patent for the purpose of reproducing speech does not seem to me to be material to the inquiry whether the fifth claim of Mr. Bell's patent 174,465 is infringed by Mr. Dolbear. The precise form of structure used by Mr. Dolbear is not found in the publications I have mentioned. His work constitutes a variation in the nature of an improvement in a well-known instrument.

ARTHUR W. WRIGHT.

NEW HAVEN COUNTY,
STATE OF CONNECTICUT, ss.

FEBRUARY 27, 1882.

Then and there personally appeared Arthur W. Wright, signer of the foregoing affidavit, and made oath that the statements therein contained are true, before me,

[SEAL] CHARLES B. MATTHEWMAN,
Notary Public.

In accordance with the stipulation on file, the complainants introduce as evidence the following from the printed record in the Dowd suit in this court: —

The Varley patent, No. 1,044, April, 1870.

Extract from deposition of Prof. Charles R. Cross, as below.

Extract from deposition of Mr. Thomas A. Watson, as below.

Extract from Deposition of Prof. C. R. Cross *in* Dowd *Suit.*

Int. 34. What must a speaking telephone accomplish with reference to the form of vibration in order to transmit articulate speech, or to transmit those peculiar qualities which distinguish one sound from another sound, when all are what are called of the same pitch and loudness?

Ans. The transmitter must take up from the air particles motions which correspond to those of the air particles themselves, and the receiver must reproduce these motions in all their complexity.

Int. 35. What characteristics must an apparatus possess in order to be able to accomplish this?

Ans. In an electrical speaking telephone, the connection between the transmitter and receiver must be such that the latter shall not be acted upon merely at separate intervals, but the armature or other moving portion of the receiver must be constantly under the influence of and guided by the variations in the electrical current caused by the motions of the armature or other vibrating portion of the transmitter; and this vibrating portion of the transmitter itself must be able to substantially take up the complex motion of the air particles which act upon it. Only in this way can the quality as well as the intensity of vocal or other sounds be reproduced, since not only the frequency of vibration but also the varying amplitude, and especially the varying form, must be reproduced in order to reproduce the quality called "articulation." The electrical current of the instrument must always present an uninterrupted path by which the continual varying current may travel from the transmitter to the receiver; that is, the circuit containing the battery or other source of electrical power, the transmitter, line wire, receiver and earth or return wire must always be closed.

Int. 36. Suppose you work your instruments with an induction

coil between the transmitter and the receiver, does that interrupt the connection or path between the transmitter and receiver in the sense in which you have used those terms? If it does not, state why not, and state what conditions must be observed as to the primary and secondary circuit when you so use an induction coil.

Ans. The circuit, under these circumstances, is not broken in the sense in which I have used that term. For successful transmission of speech in those forms of telephonic apparatus in which an induction coil is used, the primary as well as the secondary circuit must be kept uninterrupted. The operation of the induction coil is such that although no current is passed from the battery at the transmitter through the receiver, yet every variation of the primary current is reproduced by the secondary current, so that the receiver is as constantly and fully under the influence of the transmitter as if the primary current itself were transmitted.

Extract from Deposition of T. A. WATSON *in* DOWD *Suit.*

Int. 50. Have you had any practical experience as to the effect of taking away in whole or in part the casing which, in the ordinary hand telephones, encloses the space immediately behind the diaphragm, and round the coil of the magnet? If yea, state what experience you have had on that subject, and what is the result of making that change.

Ans. I have. In the summer of 1877 I had some hand telephones made for practical use, with a portion of this casing removed. About twenty-five of these were sent out to our agents. I received complaints shortly after, that they did not work satisfactory, on account of the holes back of the diaphragm, and that the agents were obliged to stop up the holes in order to make the instruments work successfully. I made a careful test myself, and saw that it would not do to leave the casing open, and had a number of telephones then in process of manufacture altered. In Indianapolis, in June of the present year [1879], I was using a telephone in which our agent had made holes back of the diaphragm. I did not know at first that the holes were there, and was surprised at the difficulty with which I heard the voice of the distant speaker. On examining, I found what the trouble was. On stopping up these holes with my fingers I could

hear much better. In my opinion, having the back of the diaphragm open would prevent the telephone from being used in many cases where there are outside noises; and I should consider that if two telephone companies were in competition, one using a closed diaphragm and the other a diaphragm open at the back, the former company would have a great advantage over the latter company.

Circuit Court of the United States.

DISTRICT OF MASSACHUSETTS.

IN EQUITY.

No. 1628.

AMERICAN BELL TELEPHONE COMPANY

v.

AMOS E. DOLBEAR ET AL.

SECOND AFFIDAVIT OF FRANK L. POPE.

Professor Cross in his affidavit in reply describes a number of experiments.

In fig. 1 (which is copied from p. 20 of his affidavit in reply) the arrangement in general use is shown.

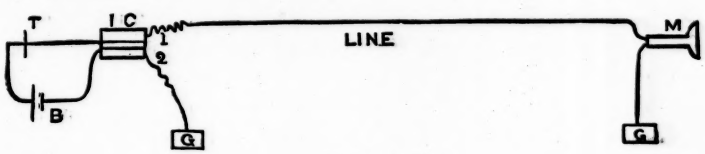


Fig. 1.

This is by far the best arrangement for the practical use of the magneto-receiver, and in my opinion, is the only arrangement now known of any practical value for using the microphone transmitter with the magneto-receiver.

Two essential features for the proper working of this arrangement are that the secondary coil should be adapted to the line, and that both ends of the line should be grounded, or (what is the same thing electrically) that a ring circuit should be used. As to the coil: the well-known law, followed in practice in all cases as nearly as possible, is that the resistance of the coil — commonly called internal

resistance — should equal that of the line including the helix of the receiver, commonly called external resistance, because such a coil with such a line furnishes the maximum current in the line, with a given generating current in the primary circuit. And the grounding or the use of a ring circuit is also essential to the best practical working of this arrangement for the same reason, the current being at its maximum when the proper coil is used with a line properly grounded at both ends, or formed into a ring circuit. Now, as the greatest possible current which can be attained with this arrangement (fig. 1) is considerably less than is necessary for speech that can be heard a yard or more from the receiver (as is well known), it is clear that any serious diminution of this current is hurtful.

April 12, 1882, I tried the arrangement shown in fig. 1 with two coils, one of which was 315 ohms' resistance — the smallest I could obtain at that time — and the other 6170 ohms.

With the smaller coil, which was about six times too large, for the external resistance was not over 50 ohms, the speech was far louder than with the larger coil. I am satisfied, from the perfectly familiar laws governing this matter, that a considerably better result would have been obtained with a coil of 50 ohms than with the 315-ohm coil; and found a very marked difference in loudness between the 315-ohm coil and the 6170-ohm coil, the 315-ohm coil giving far better results than the 6170-ohm coil.

This difference is in accordance with the familiar laws governing this matter, which are so well known that all good workmen set up telephone lines in accordan e with them. I will here briefly explain as to this.

The soft iron core in connection with the secondary coil constitutes a magneto-electric generator. Whenever the magnetism of the core is increased by the action of the primary a difference of potential is set up in each convolution of the secondary coil, tending to produce an electric current of a given polarity or direction. When the magnetism of the core is diminished the same effect is produced, but in a reverse direction, tending to produce a current of a polarity opposite to the first one. The strength of current generated by the coil in any particular case is determined by Ohm's

law; viz., by dividing the electro-motive force, as measured by the potential, by the resistance of the conductor. If we wish to produce the most powerful effect in a Bell or electro-magnetic receiver it is necessary to produce the strongest possible current; we therefore wind the secondary wire a sufficient number of times around the core in the form of a helix. If we assume as a unit of potential the potential which is set up in a single convolution of the wire, and as a unit of resistance the resistance of a single convolution, we shall obviously increase the electro-motive force and the resistance in equal increments by each added convolution. But inasmuch as all the electro-motive force in the circuit is within the secondary coil, while the resistance is partially within and partially without, including as it does the line wire and the helix of the receiving instrument, it is evident that by this mode of procedure we at first increase the total electro-motive force of the circuit at a more rapid rate than we do the total resistance; and hence we produce an increase in the strength of current in the whole circuit as each convolution is added. The length of the iron core around which the secondary circuit is thus wound is, however, limited by other considerations, inasmuch as a core must be comparatively short in order to be magnetized and demagnatized with sufficient rapidity for telephonic purposes. Hence it is necessary, after having covered the admissible length of the core, to wind another layer of convolutions upon or outside of the first layer. In this second layer the electro-motive force of each convolution is a little less than in the first, because of its greater distance from the core, while its resistance is greater in consequence of its larger diameter and consequent greater length of wire. Thus as we superpose one layer upon another the resistance of the coil increases more and more rapidly in proportion to its electro-motive force, until we ultimately arrive at a point where a current produced by the increased electro-motive force in each convolution is more than counteracted by its increased resistance. This is found to occur when the resistance of the wire of the secondary coil nd t hat of the line are approximately equal, and any increase in the number of convolutions beyond this point results in a decrease of the current. Hence the law of the construction of the Bell secondary for

producing the strongest possible current is to maintain the resistance of the coil as low as possible in proportion to its electro-motive force, for the reason that keeping down the resistance increases the strength of current, and a very low potential is of no consequence, provided the strength of the current is adequate.

I also tried the arrangement shown in fig. 4 (copied from p. 23 of Cross' affidavit in reply) with the 6170-ohm coil,

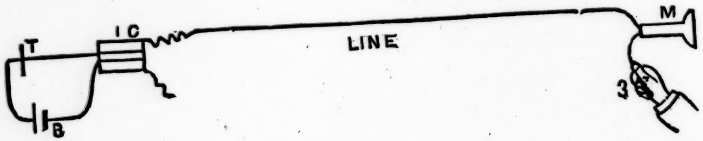


Fig. 4.

and found that the speech was very faint, but could nevertheless be understood when the room was perfectly free from external sounds. It was not comparable to the speech in fig. 1. I am surprised at the statement of Professor Cross, that "with this arrangement, fig. 4, . . . the transmission was as good as with No. 1." If he means by "transmission" to include loudness or volume of sound, he is certainly wrong. The current in the line in fig. 4 is only a very small fraction of that in fig. 1, and the work it can do is consequently very much less than the work done by the current in fig. 1; and this is mathematically true. The current in fig. 4 is what is known as a current of charge, that is, the line not being grounded or a ring circuit, the current is only that which results from the charging of the line, including the helix of the receiver and the reservoir at the end of the line, — in fig. 4 a human body; and this current is, as I have said, a very small fraction of the current in fig. 1. I did not try the smaller coil with fig. 4, because it was clear to me that the results would have been much less than those obtained from the larger coil, the external resistance being infinite.

I also tried the arrangements shown in figs. 3 and 5 (copied from pp. 22, 23 of Cross' affidavit in reply),

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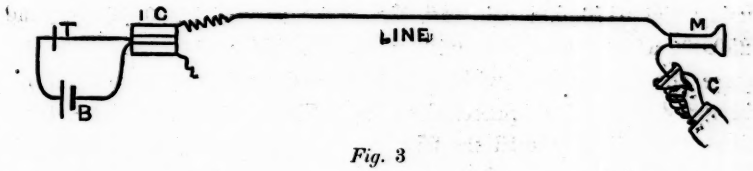

Fig. 3

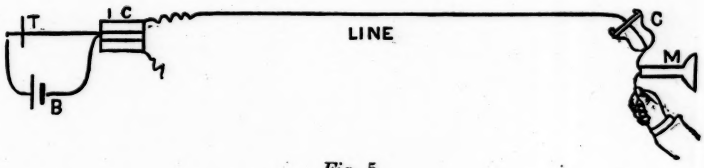

Fig. 5.

and found the results the same in each.

The Bell transmitted speech perhaps somewhat louder than in fig. 4, but far fainter than in fig. 1. There was very little difference between the results from the Bell receiver in figs. 3, 4 and 5; neither of them could be heard except in an absolutely still room; the slightest external noise drowned them. The Dolbear receiver in figs. 3 and 5 gave out very loud and distinct speech. In these trials I used the 6170 ohm coil. The currents in figs. 3, 4 and 5 are currents of charge, and the magneto-receiver is of no practical utility in either of these arrangements.

I also tried the arrangements shown in figs. 6 and 7 (pp. 23, 24, Cross' affidavit in reply),

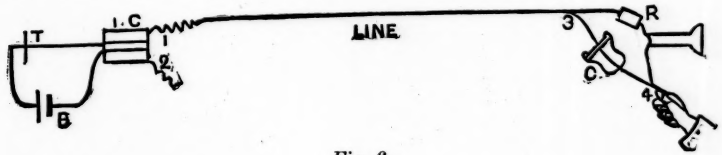

Fig. 6.

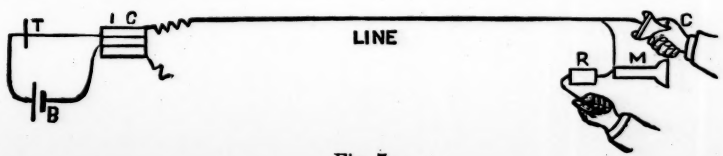

Fig. 7.

using the 6170-ohm coil, and the resistances of 12,000, 50,000 and 250,000 ohms; and also without any added resistance. The Bell gave the best results with no added resistance, the same results as in fig. 4, and of no practical value. The results from the Bell differed very slightly until the 250,000 ohms' resistance was used, when the sounds became so faint that although I could hear the sounds I could not distinguish articulation.

When no resistance was added no sound was audible from the Dolbear receiver; when 12,000 was used both receivers were about alike, Bell perhaps slightly better, but both very faint; I concluded that with about 15,000 ohms they would have been about the same, but neither of any practical use. With 50,000 Dolbear good, and with 250,000 Dolbear loud and clear. So far as concerns the Bell receiver, figs. 6 and 7 are substantially the same as figs. 3, 4 and 5; and so far as concerns the Dolbear receiver, figs. 6 and 7, with the high resistance, are substantially the same as fig. 2.

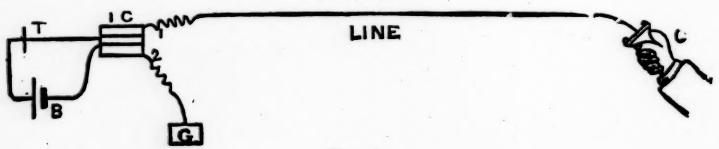

Fig. 2.

I did not try the precise arrangement shown in fig. 8, for the reason that the front plate of Dolbear is described as a part of the line wire, and therefore this arrangement does not differ from fig. 7.

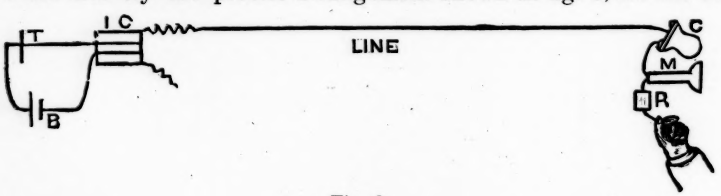

Fig. 8.

I tried the arrangement shown in fig. 9, and found that this gave results much nearer fig. 1 than any of the other arrangements.

7

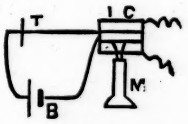

Fig. 9.

Although not so good as fig. 1, this was much better than any of the others. The reason is that this has two reservoirs, each of considerable capacity, with the helix of the receiver forming a part of a conductor which connects the two reservoirs. In fig. 1 the two reservoirs are G G, and the generator is I C, while in fig. 9 the two halves of the coil I C are the reservoirs and also constitute the generator. What happens in fig. 9 is that the electricity in both halves is forced out of one half and into the other, — one half becoming an electric vacuum, the other an electric plenum, — and is compelled, therefore, to flow through the helix between them; the work done depending wholly upon the current from one half of the coil to the other, just as in fig. 1 the work done depends wholly upon the current which flows from G to G.

The fact that it is physically impossible to repeat this experiment (fig. 9) with the Dolbear receiver substituted for the Bell receiver, tends to confirm me in my opinion that the two systems are radically different. Fig. 9*a* shows an arrangement which is as near as

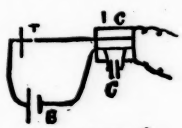

Fig 9. A.

it is physically possible to come with the Dolbear receiver to fig 9; but this arrangement is radically different from fig. 9, for here there are two distinct secondary coils, instead of two halves of one secondary coil, and each of these two coils is an independent generator, and a generator only, not a reservoir. What happens here is that the electricity in each coil is forced as far as it will go under the stress employed towards one end of that coil; and consequently one

of the plates of the Dolbear receiver becomes an electric plenum, the other end of its coil becoming an electric vacuum, while the other plate becomes an electric vacuum, and the other end of its coil an electric plenum.

In fig. 9 one half of the coil is a vacuum when the other half is a plenum, and *vice versa;* while in fig. 9*a* one half of each coil is a vacuum while its other half is a plenum, and *vice versa;* or, in other words, there is but one coil in fig. 9, while there are two coils in fig. 9*a*. Fig. 9 cannot be expected to give so good results as fig. 1, no matter what coil be used, because the current must be less than if the ends of the coil were grounded. In fig. 9*a* the resistance is infinite, and if the number of convolutions in either coil be such as to produce the proper variations of charge in the two plates of the Dolbear receiver, it will work just as well as in any other arrangement.

In my opinion these experiments seem to demonstrate more conclusively the correctness of the statement made in my former affidavit in this case, viz., that the two methods respectfully utilize two wholly unlike properties or characteristics of the electrical energy which is manifested in the secondary of the induction coil at the sending station.

The experiments show that the linear conductor may be placed in an electrical condition in which both the properties referred to coexist to a sufficient extent to simultaneously operate the Bell and the Dolbear receivers. Yet it is nevertheless true that just so far as the conditions are changed to favor the working of either receiver, the working of the other receiver is thereby impaired. For example, the organization shown in fig. 1 of Cross' affidavit is that ordinarily employed in the practical operation of the Bell receiver, in which is used an induction coil having secondary of a comparatively small number of convolutions and of low resistance, by which the best results are obtained.

If in this organization a Dolbear receiver be substituted in place of a Bell receiver, no perceptible useful effect is produced therein, as Professor Cross himself states on page 26 of his affidavit in reply.

On the other hand, the organization shown in fig. 2, by which the best results are obtained with the Dolbear method and apparatus, comprises an induction coil having a secondary of many convolutions and of high resistance, which is united to a line disconnected or open at the receiving end. If a Bell receiver is placed in this circuit in the manner shown, for example, in fig. 4, the sounds produced therein are extremely feeble.

Although the secondary of the induction coil employed by Dolbear is apparently substantially the same as that of the coil employed by Bell, the two differing only in respect to the number of convolutions of the secondary around the core and the resistance of the coil, yet in my opinion this statement does not express the real difference between them.

I have already explained the laws in accordance with which the secondary coil used in the Bell system must be constructed to produce the best results, and I will now explain the laws which control the Dolbear system, so far as the secondary coil is concerned.

In the construction of the Dolbear coil the object in view is to produce the highest possible potential, irrespective of the resistance incidentally caused thereby. We therefore use a fine wire enabling a very great number of convolutions to be placed within the necessary space, whereby we get a very high potential, though the resistance of the coil may amount to many thousand ohms.

That the conditions necessary in order to secure the best results by the methods of Bell and Dolbear, respectively, are not the same, but, on the contrary, are to a great extent antagonistic, is well shown by the experiments of Professor Cross illustrated in fig. 6, page 28 of his affidavit, in which the line is divided at the receiving station into two branches, one of which is an open and the other a closed branch. The open branch contains the Dolbear receiver, and the closed branch the Bell receiver. An adjustable resistance is interposed in the closed branch, and upon removing this resistance altogether so as to permit a current to flow freely to a reservoir of sufficient capacity the Bell receiver operates as well as it can in an open circuit, while the Dolbear receiver does not operate at all, for the reason that the difference of potential between its plates is prac-

tically nothing. As the resistance R is increased the sound in the Dolbear receiver becomes perceptible and continues gradually to increase in loudness, while, on the other hand, that in the Bell receiver gradually decreases. This result necessarily follows, from the fact that the electric potential at the receiving end of the line is gradually increasing as more and more resistance is interposed, while the strength of current at the same point is gradually decreasing. In other words we are enhancing that property of electricity in the line by virtue of which the Dolbear receiver acts, and suppressing that property by virtue of which the Bell receiver acts. If the resistance be made great enough, the Bell receiver will become quite silent, while the Dolbear receiver will then produce sounds of maximum loudness.

This experiment shows what Professor Cross himself admits (pp. 31, 32), that the electricity in the conductor has two properties, and that if we place the two receivers side by side in the same conductor, one property moves one, and the other property moves the other.

I believe Dolbear to have been the first to discover that one of these properties of electricity (that which he uses) could be made available for the utilization of magnetic variations of the peculiar kind necessary to produce articulate sound.

Professor Cross refers to certain particular pieces of apparatus in existence prior to the date of Bell's patent, in which he says electrical variations in the secondary circuit of an induction coil were utilized to produce sounds by causing vibratory movements in plates, viz., those of Wright, Varley and Thompson, the construction and operation of each of which he describes at some length. Unless Professor Cross here uses the term "electrical variations" in a wholly different sense from that in which he has used it elsewhere (as, for example on page 4 of his affidavit in reply), as defining an electrical condition which increases or decreases gradually as distinguished from a condition which passes suddenly from zero to maximum and from maximum to zero, the examples cited, all of which were known to me at the time of making my former affidavit, do not appear to me to sustain his statement, or to refute the state-

ment made by me. In the description of the transmitter of Wright which was the same as that of Reis, it is distinctly stated by Professor Cross (p. 38) that the primary circuit was made and broken; and the same statement is made with reference to that of Varley. Sir William Thompson also states that his condensor, from which sounds were produced, was charged and discharged suddenly; and Professor Cross says the same thing as to similar experiments of his own (pp. 38, 39). The changes produced in the primary coil in all these cases were not of electrical variations in the sense in which this term is used in the Bell patent.

In speaking of the current in the primary circuit of the Bell and the Dolbear apparatus, Professor Cross himself states (p. 4) that the special form of electrical variations in the primary circuit is the cause of the special form of electrical variations in the secondary circuit. Hence the knowledge of the fact that a sound having a definite pitch, although destitute of quality, could be produced in a condensor connected with the terminals of a secondary coil, by making and breaking a current of uniform strength in the primary coil, cannot have imparted to any one the knowledge that a continuous current of varying strength in a primary circuit would produce sounds in a condensor varying in loudness and quality as well as pitch. It has not yet been shown that any person had this knowledge prior to the discovery of Professor Dolbear, and if such be the case, in my opinion the use of a condensor in this manner is something absolutely unlike, and therefore not an employment of a well-known substitute for, the receiver of Bell.

As I understand the affidavits of the complainants in reply it is sought by means of them to establish two points: first that the electrical condition in the secondary coil and in the linear conductor, by virtue of which the vibrating plate of the receiver is controlled by that of the transmitter, is essentially the same in Dolbear's method as it is in Bell's; and second that the receiver of Dolbear, consisting of a resilient plate which is caused to vibrate by varying electrical attraction, is a well-known substitute or equivalent for the receiver of Bell, in which a similar plate is caused to vibrate by varying magnetic attraction.

I have no doubt that the electrical condition in the secondary coil and in the conductor is radically different in the two methods: and I believe Dolbear was the first to discover that the electrical condition used in his method could be used.

Professor Cross states that electrical undulations similar in form to the sound-waves to be transmitted are produced in both apparatuses by the sound-waves at the sending end, and these undulations are in turn the cause of the sound-waves heard at the receiving end. This is unquestionably true, and it is the inevitable physical condition of the use of electricity for the transmission of speech. I understand him to draw from this fact the conclusion that not only Dolbear's method and apparatus, but any method or apparatus whatsoever by which electrical variations of any character similar in form to the sound-waves to which they are due are employed to produce similar sound-waves at another point, is embraced within the scope of the fifth claim of Bell's patent; that is to say, that every such method is of necessity substantially the same as the method described by Bell.

My attention is called to the statement of Professor Cross, on page 12 of his affidavit in reply, that "electrical signals are generally given by electrical variations." This is not so unless the word "variations" be used loosely. All ele ctric signals were given until within a few years, by the presence or absence of a current, and not by variations of current. It is true that a galvanometer needle would show variations of current which did not succeed each other too rapidly; but no use has ever been made of this for signalling. All signalling instruments known to me before Gray's universal receiver were operated by the presence or absence of given strengths of current, and not by variations of current. And no use whatever was ever made of variations of charge, so far as I know or have any reason to believe, before Dolbear discovered that they could be used.

FRANK L. POPE.

Subscribed and sworn to before me this 29th April, 1882.

[SEAL] W. C. WITTER,
Notary Public, N. Y. Co.

13

SECOND AFFIDAVIT OF HENRY C. BUCK.

HENRY C. BUCK, of lawful age, being duly sworn, says,—

I have already given an affidavit in this case.

I have carefully read the affidavits in reply on behalf of the complainants, and have in connection with Mr. Frank L. Pope repeated the experiments spoken of by Professor Cross.

I first knew of the Dolbear system in 1879, and have repeatedly performed experiments, the same in all material respects as those mentioned by Mr. Cross (except fig. 9), during 1880 and 1881.

On April 12, 1882, I tried two secondary coils, as in fig. 1, one of 315 ohms, the other of 6170 ohms, and have tested many other coils in fig. 1, up to 10,000 ohms. The smaller one was far too large for the best results, and with the larger one the speech was much weaker.

These results are in accordance with familiar laws so well known that no practical workman would think of using a 315-ohm coil with a line whose resistance was only 50 ohms, and expect to get so good a result as with a 50-ohm coil. A single cell or a single convolution of a secondary coil (both generators of electricity) will give as great a current as can be obtained from any number of like cells or convolutions, if there be no external resistance.

For if you use one generator without external resistance the current you get is volts divided by ohms, say $\frac{1}{1} = 1$, where the numerator represents the electro-motive force, the denominator, the internal resistance, and the quotient, the current. Now two like generators, arranged to double the electro-motive force, will also double the resistance, and will give $\frac{2}{2} = 1$; the quotient being the same as before, because dividend and divisor are both doubled; and so as to any number of generators, each like all the others, so long as there is no resistance except that of the generators themselves, or internal resistance.

But in a secondary coil for use with a telephone the core must be short, and therefore the convolutions of the coil must be in layers; and it is only those convolutions which make up the inner layer which give the maximum current, those of the next layer generating

slightly less electro-motive force, and offering a slightly increased internal resistance, and so on: so that a coil with but one layer of convolutions will, if there be no external resistance, give the same current as a single convolution, while a coil of two layers will give slightly less current than a coil with one, and a coil with three, slightly less than one with two, and so on, until you reach a limit where the potential is so high and the resistance so great that it is practically impossible to insulate the convolutions from one another, the current passing through the insulating material in preference to traversing the wire of the coil, because the resistance of that material to its passage is less than the internal resistance of the coil, and the potential is high enough to overcome the resistance of the insulating material.

In fig. 1 the current flows from G to G; that is to say, every increase in the magnetic energy of the core tends to make one end of the coil an electric vacuum, and its other end an electric plenum, and every decrease, *vice versa;* but as the resistance is slight, electricity flows into the vacuum end from one G and out of the plenum end into the other G, the current being the quotient, obtained by dividing the potential by the resistance. But it should also be noted that potential depends not only upon the number of cells or convolutions used, but also upon resistance, for with a given quotient and divisor there can be but one dividend. If a generator could be conceived wholly without internal resistance, the electricity generated by it would be without potential; and the largest battery or coil will give no more potential than enough to overcome the total resistance — external and internal. Consequently, if the potential and current be given, the resistance follows; if the resistance and current be given the potential follows; and if potential and resistance be given the current follows. This is Ohm's law.

Figs. 2 and 3 show two forms of the Dolbear apparatus, both well known to me. In both the resistance is infinite, and consequently there can be no current except what is known as a charging current, which is that current which is essential in order to redistribute the electricity of an insulated body. Professor Wright says (p. 57) that Ohm's law does not apply to these currents of charge, and also

that that law does not apply to the currents in fig. 1. He is certainly wrong in this; every telephone line ever heard of before Dolbear's discovery was subject to Ohm's law. Perhaps Professor Wright may mean nothing more than that Ohm's law does not apply to the modifications of Bell's system shown in figs. 2, 3, 4 and 5 (pp. 60, 61). But he is wrong even in this; all currents, no matter how brief, are subject to Ohm's law; although his application is more readily perceived in the case of what Professor Wright calls "steady currents," it is of course equally applicable to all currents, for a current can only exist when potential causes a flow of electricity in spite of the resistance of a conductor; and currents of charge are just as truly under Ohm's law as any other. The main difference is that currents of charge are simply the flow of electricity from one part of an insulated body to another part of that body, while Professor Wright's "steady currents" are flows of electricity over a closed circuit.

Take figs. 2 and 3 (pp. 21, 22 complainants' affidavits in reply for illustration. Here the electricity in the line (from G to C, fig. 2, and the coil I C and line, fig. 3) is redistributed at every charge of the magnetic energy of the core. In one case (say an increase of magnetic energy) it flows as far as it can be forced by that increase of energy towards the terminal C, and C becomes an electric plenum; the electric pressure or potential in C and all the line being that of the plenum end of the coil I C. So long as this flow lasts there is a current of charge over the line. If the primary circuit were an open circuit and then suddenly closed, the current of charge in the secondary would begin as soon as any current passed, through the primary, and rapidly rise to its maximum and then rapidly fall to zero; and a reflux current would instantly follow restoring the equilibrium disturbed by the sudden magnetization of the core, the whole occupying a small fraction of a second. The grounding of the free end of the coil I C, as in fig. 2, only slightly increases this current, and has very little effect upon the potential of the plenum end of the coil. On breaking the primary the sudden demagnetization of the core will cause a current of charge to flow over the line in the opposite direction, rapidly rising to its maximum

and then rapidly fall to zero; and a reflux current will instantly follow to restore the equilibrium. The outflow into G, fig. 2, in the latter case, and the inflow from G in the former case, being very much less than it would be if both ends of the coil I C were grounded.

In fig. 2 the variations of magnetic energy in the core conform of course to the variations of current in the primary circuit which cause them, and these variations of magnetic energy cause the potential of the coil and line and front plate of C to vary in like manner; and this varies the attraction between the two plates of C, and gives the front plate the necessary motions to cause air-waves like those which move the diaphragm of the transmitter, provided the potential be very high. The same statements are true of fig. 3. I have no doubt that these variations of high potential like in form to the sound-waves (by which they are indirectly produced) are wholly new with Professor Dolbear, and that their precise action cannot be determined by reasoning from anything now known, but can only be ascertained by repeated and excessively delicate experiments.

In the Dolbear system a very great number of convolutions are necessary in the secondary coil, a very high potential being essential. Consequently the two controlling elements in setting up a Bell line, a proper coil, with its internal resistance equalling the external resistance of the line, and proper grounds or a ring circuit (without both of which no practical Bell line can be constructed), are both wholly disregarded in the Dolbear system.

In fact, the generation of Dolbear's variations of high potential is incompatible with the generation of Bell's variations of current strength; and both instruments cannot be made to do good work in the same line, for the reason that the nearer right the line is for one, the worst it is for the other.

I have read Mr. Pope's affidavit in rebuttal, and fully corroborate all he says about the experiment shown in figs. 1 to 9, both inclusive pages 21 to 25 complainants' affidavits in reply; and also about fig. 9*a*.

I have frequently tried the experiments fig. 11 (p. 26 complainant's affidavits in reply), and have never had the least difficulty in

getting perfect speech from the Dolbear receiver with 1,000,000 ohm's resistance in the line, as described by Mr. Cross. I have never been able to get speech from the usual magneto-receiver with anything like 1,000,000 ohms in the line as in fig. 11. I can get excellent speech with the Dolbear, with 1,000,000 ohms' resistance in the line, with a coil of not over 3000 ohms.

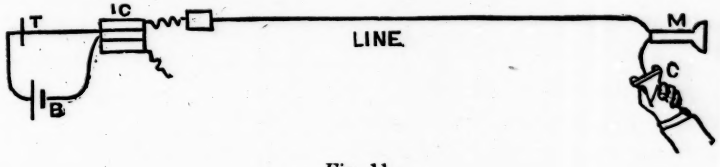

Fig. 11.

The conclusions drawn by Professor Cross from this experiment seem to me radically wrong in one particular, for the resistance interposed between the end of the secondary and its terminal certainly would (and the experiments shows that it did) tend to "prevent the transmission of 'electric pressure,'" just as a very small pipe between a cylinder and a small vessel would prevent a sufficient flow of water into the small vessel from the cylinder, if its piston were forced down even with an enormous force but for a very short time; whereas if the pipe were larger, the pressure in the small vessel would instantly equal that in the cylinder. In both cases there is pressure—water pressure in one, electric pressure in the other, in both cases this pressure is to be exerted at a distant point; in both cases the fluid under pressure must flow to that point and fill up a small vessel there, the pressure in that small vessel being what does the work; in both cases the time is short during which the pressure is exerted on the fluid in the larger vessel, — the cylinder in one case, the coil in the other; and consequently in both cases if the flow be obstructed it will take a longer time to fill the small vessel.

For the proper working of the Dolbear receiver the plate connected with the coil should vary its potential instantaneously with the varying of the coil; and that is what happens unless there be an obstruction interposed between them. The resistance in fig. 11 is such an obstruction, and may be likened to an excessively small

pipe preventing the flow of water from a large vessel to a smaller one and back again.

On page 28 Mr. Cross says that "the experiments Nos. 6, 7 and 8 show that leakage, due to imperfect insulation, also affects the [Dolbear] apparatus seriously." This is a mistake, as the apparatus is not appreciably affected by leakage, the "insulation resistance" of any line fairly well constructed, being ample under the most unfavorable conditions. The results have been found excellent between Boston and New York with the Dolbear apparatus, both in dry and wet weather. As to "insulation resistance," theoretically it is more difficult, somewhat, to insulate the Dolbear line than the Bell; but the ordinary insulation resistance is abundant for the Dolbear line.

The best line for the Dolbear system is a fine wire, with as little superficial area as is consistent with durability, for the reason that Dolbear utilizes variations of charge, and the great resistance of such a line is unimportant in his system; and this is as unfavorable a line for the Bell system as can be imagined, because of its high resistance.

Until after Professor Dolbear's discovery I never knew or heard of any Bell apparatus, except with a closed circuit; and it was Professor Dolbear's discovery that led me to try the Bell apparatus without a closed circuit. Before Professor Dolbear's discovery the only electric variations which were known as capable of use in the transmission of speech were of low electro-motive force, namely, that suited to the low resistance in the line, and did their work by flowing through a helix to ground. The diagram annexed, fig. B, fairly represents these variations, the lower line indicating zero of potential and the second line the potential of the Bell currents; and these currents each varied in potential from maximum at the end of the coil to zero at ground.

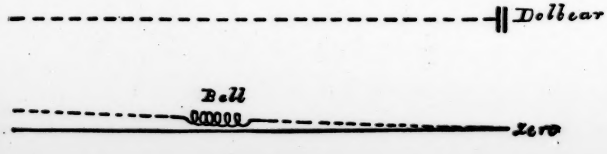

Fig. B

Dolbear's variations are represented in fig. B by the upper dotted line, but not quite fairly, as the distance from the base line should be multiplied many times, if the distance of the Bell line above the base line be taken as representing the electro-motive force of the Bell variations. The Dolbear line should be in such a diagram at least thirty times farther from the base line than the Bell line is.

Fig. B fails to represent another vital difference between the variations used in the two systems. That difference is based upon the well-known fact that if magnetic energy be converted into electric energy, it may be converted into electric energy in which the dynamic property greatly exceeds the static, as in the galvanic current, or into electric energy in which the static property greatly exceeds the dynamic, as in lightning. A given magnetic energy can be converted into only a certain amount of electric energy; but with one apparatus for converting it—an induction coil of say 500 convolutions—the dynamic can be made to greatly exceed the static, while with another apparatus for converting it—an induction coil of say 20,000 convolutions—the static can be made to greatly exceed the dynamic. But the dynamic cannot be increased, except at the expense of the static; and the static cannot be increased, except at the expense of the dynamic; for the electric energy is the sum of the two, and cannot exist in the absence of either. In a stroke of lightning the dynamic is at its minimum, while the static is at its maximum: in a current from one large cell the dynamic is at its maximum, and the static at its minimum. Bell's system utilizes the dynamic, and it is physically impossible to operate the Bell apparatus with the static; and in the best electric energy for the Bell the dynamic must far surpass the static. Dolbear's system utilizes the static, and it is physically impossible to operate the Dolbear apparatus with the dynamic. In the best electric energy for Dolbear the static must far surpass the dynamic.

HENRY C. BUCK.

UNITED STATES OF AMERICA,
DISTRICT OF MASSACHUSETTS,

SUFFOLK, ss. BOSTON, April 29, 1882.

Then personally appeared the above-named Henry C. Buck, and made oath that the foregoing affidavit, subscribed by him, is true.

Before me,

[SEAL] WILLIAM A. COPELAND,
Notary Public.

[*From pp.* 399, 400 *of the Record, Bell Telephone Company et al.* v. *Peter A. Dowd.*]

DEPOSITION OF CHARLES R. CROSS.

Int. 34. What must a speaking telephone accomplish with reference to the form of vibration in order to transmit articulate speech, or to transmit those peculiar qualities which distinguish one sound from another sound, when all are what are called of the same pitch and loudness?

Ans. The transmitter must take up from the air-particles motions which correspond to those of the air-particles themselves, and the receiver must reproduce these motions in all their complexity.

Int. 35. What characteristics must an apparatus possess in order to be able to accomplish this?

Ans. In an electrical speaking telephone the connection between the transmitter and receiver must be such that the latter shall not be acted upon merely at separate intervals, but the armature or other moving portion of the receiver must be constantly under the influence of and guided by the variations in the electrical current caused by the motions of the armature or other vibrating portion of the transmitter; and this vibrating portion of the transmitter itself must be able to substantially take up the complex motions of the air-particles which act upon it. Only in this way can the quality, as well as the intensity or other sounds, be reproduced, since not only the frequency of vibration but also varying amplitude, and especially the varying form, must be reproduced in order to reproduce the

quality called "articulation." The electrical circuit of the instrument must always present an uninterrupted path by which the continually varying current may travel from the transmitter to the receiver, that is, the circuit containing the battery or other source of electrical power, the transmitter, line wire, receiver and earth or return wire must always be closed.

[*From pp.* 221-231 *of the Record, Bell Telephone Company et al.* v. *Dowd.*]

DEPOSITION OF EDWARD S. RENWICK.

Int. 32. I call your attention now to the sixth claim of the second Bell patent, namely, "The combination, with an electric telephone such as described, of a sounding box, substantially as herein shown and set forth." Mr. H. B. Renwick at the foot of page 23 of the printed record, says of this cover or sounding box that it "encloses that end of the diaphragm which is farthest from the speaker at one end, or the hearer at the other, and thus prevents vibrations of the air, due to the noises in the room or other causes, from affecting the vibration of the diaphragm." If there is any practical liability to undersigned vibrations of the diaphragm when it is not enclosed, is it liable to such vibrations to be produced from the side of the diaphragm which is nearest to the speaker at one end, or the hearer at the other, as well as on the side which is farthest from him? And if yea explain why.

Ans. The diaphragm is liable to be influenced quite as much by undersigned vibrations or extraneous noises made at the side which is nearest to the speaker or to the hearer, as it is at the opposite or rear side. Because the speaking-tube E separates the speaker or hearer from the diaphragm, so that if the diaphragm is not protected at its face side by a cover, extraneous noises would pass to it all around the end of the speaking-tube nearest the diaphragm, which end is less in diameter than the coil of wire G at the back of the diaphragm, and therefore would protect the diaphragm or plate from

noises in front to a less extent than the intervention of the coil of wire G would protect it from noises in the rear of the plate or diaphragm.

Int. 33. If there is any practical liability to extraneous vibrations of the diaphragm, such as Mr. H. B. Renwick says the sounding box in the Bell patent protects the diaphragm from on the side farthest from the speaker or hearer, what is it in the said patent which protects the diaphragm from such extraneous vibrations on the other side?

Ans. It is the square piece of wood which, in the telephone represented at figs. 1, 2 and 3 of the said Bell patent, covers the front or face of the diaphragm, and is perforated only by a hole in which the end of the speaking-tube E is inserted. This front board covers the front of the diaparagm, and protects it from all noises or vibrations in front, except the sounds which are purposely applied through the speaking-tube E.

Int. 34. Assuming for the present that there is practical advantage in covering the diaphragm with a so-called sounding box which protects it from extraneous vibrations, will you state whether you find, in any of the instruments testified as used by Mr. Gray prior to the Bell patent, the combination with an electric telephone (having an electro-magnet and a plate of inductive metal or its equivalent as mentioned in Bell's third claim) of a sounding box which protects the diaphragm or its equivalent from such supposed extraneous vibrations? And if so, specify the instrument, and explain its similarity in this respect to the Bell arrangement.

Ans. If the covering with the so-called sounding box includes the covering of the rear side only of the diaphragm or plate, then I find that substantially the same covering or box is found in the "Defendant's Exhibit Diaphragm Box Magnet Receiver." This instrument contains an electric telephone such as is described in the said Bell patent No. 186,787; that is, an electric telephone composed essentially of an electro-magnet and a plate of iron supported in front of the said electro-magnet at a short distance from the poles or core thereof, the magnet within the box being such electro-magnet, and

the perforated head of tin-plate or tinned iron being the plate of iron capable of inductive action.

The covering in this defendant's exhibit is formed by the cylindrical wall of the box and the wooden head thereof, which protect the rear side or back of the induction plate from noises or vibrations which are produced at that side of the instrument.

The said Bell patent, as before stated by me, contains the statement that "in lieu of Plate A" (the induction plate) "in above figures" (which are all the figures represented in the drawings of the patent), "iron or steel reeds of definite pitch may be placed in front of the electro-magnet O. . . ," which statement, as previously explained, by me under division fifth of my answer to interrogatory 30 amounts in substance to a statement that the patentee considers two or more steel reeds, when placed in front of one electro-magnet, as a substitute or equivalent for the induction plate A; and therefore, as I understand the patent, this substitute is included by the language of the claims. Therefore I am of opinion that the "Defendant's Exhibit Gray's Two-octave Transmitter" contains in substance the combination with an electric telephone (having an electro-magnet and the substitute or equivalent mentioned in Bell's patent for a plate of induction metal) of a sounding box which protects the equivalent or substitute for the diaphragm from the supposed extraneous vibrations mentioned in the question. in the case of this defendant's exhibit, each of the electro-magnets corresponds with that required by the said claim; and each set of two or three steel reeds of definite pitch, which are placed in front of one of those electro-magnets, corresponds with the substitute or equivalent for the induction plate A mentioned in the sentence of the said Bell patent above referred to by me. In this defendant's exhibit, also, there is a cover or sounding box, which covers each electro-magnet, and each set of reeds, which is combined with one electro-magnet and protects these reeds (which, according to the said sentence of the Bell patent, are a substitute for the induction plate) from the action of extraneous vibrations. When the cover is closed, these Bell substitutes or equivalents for the induction plate are protected from such extraneous vibrations both in front and rear. When the cover is raised so as to be upright, it protects the

said Bell substitutes for the induction plate from extraneous vibrations made at their rear.

Int. 35. Do you believe that there exists in practice any such liability as Mr. H. B. Renwick says the sounding box in the Bell patent provides for, namely, liability of the diaphragm, either at the end farthest from the speaker or hearer, or at the end nearest to him, to have its designed vibrations affected by undersigned or extraneous vibrations, "due to noises in the room or other causes", and will you describe any practical observations you have made for the purpose of testing your judgement upon this matter?

Ans. I do not believe that in practice any such liability exists. I have experimented with two forms of Bell telephone; which I was informed were manufactured by the Bell Telephone Company, such experiments being made by me in company with Mr. William M. Goodridge and Frank L. Pope. The experiments were made in a noisy locality, the instruments being tested with and without the covers, and both as transmitters and receivers. With one form of instrument I could not distinguish any difference in either the distinctness or loudness of the sounds transmitted or received, whether the cover was on the instrument or removed from it. With the other form of instrument I could not distinguish any difference whatever in any trial but one, in which both the mouthpiece and cover, or plate in front of the metallic plate, were removed, as well as the entire covering in the rear of it. With the instrument in this condition, and used as a receiver, the articulation was materially more distinct without any cover in the rear of the metallic plate than when the cover at that side was in place.

Int. 36. Coming now to the seventh claim of the second Bell patent, namely, "In combination with an electric telephone, as herein described, the employment of a speaking or hearing tube for conveying sounds to or from the telephone, substantially as set forth"; this speaking tube, which is marked E in the patent, Mr. H. B. Renwick says, in his opinion, "really means the tubular orifice through which the sound-waves are sent, in connection with the chamber at the end of that orifice where the sound-waves act upon the diaphragm." State whether you think that the speaking-tube E really includes the

chamber, being, as I understand it, the space between the front face of the diaphragm and what you have spoken of as a part of the sounding box or cover, within which space the vibrations of the diaphragm take place.

Ans. In my opinion the speaking-tube E mentioned in the patent does not include the chamber referred to, because the chamber is not what would be commonly called or understood as any part of a tube, and because there is no statement or suggestion in the patent that the speaking-tube mentioned includes the square piece of board into which its end is inserted, and whose inner side forms a shallow square chamber in front of the plate or diaphragm. Thus, the only language that I have found in the patent in relation to the speaking-tube are the following sentences: "E represents a speaking-tube by which sounds may be conveyed to or from the plate A", "for convenience of operation through the speaking-tube E"; "to listen to his telephone preferably through the speaking-tube E"; "to convey an articulate message it is only necessary for an operator to speak in the neighborhood of his telephone, preferably through the tube E"; lastly, the words in the claim, the employment of a speaking or hearing tube for conveying sounds to or from the telephone." The drawings show the letter E placed upon the tube only; and, in the absence of any special description to the contrary, I understand the speaking tube referred to is that tube, and does not comprehend the plate or board to which it is attached, which, so far as the tube is concerned, is simply a means for holding it in place, and might, according to my understanding, be replaced by any other suitable device for that purpose without changing substantially the character of the speaking-tube described, or its combination with the telephone. If, for example, the said plate or board should be removed, and a narrow bridge straddling the plate, or a single arm projecting from one side of the plate A to the end of the speaking-tube, should be employed in the telephone represented at figs. 1, 2 and 3, the combination recited in the said seventh claim would, in my opinion, exist as certainly as it does in the instrument constructed with a square plate or board; yet, in the case of each of said substitutions

there would be no enclosed chamber of the front side or face of the induction plate or diaphragm A.

Int. 37. Assuming that the chamber forms no part of the speaking-tube, will you refer to the Bell patent of 1876, and say whether you find there substantially the same speaking-tube to speak through or listen through, in combination with a diaphragm, towards which vibrations produced by vocal sounds are directed, or from which they are received?

Ans. Whether I do or do not, depends upon how much or how little is understood to be comprehended by the term "speaking-tube." If, for example, the term "speaking-tube" is understood to comprehend what is commonly termed a mouthpiece, by means of which sounds spoken into it are prevented from spreading laterally and are thus concentrated, then I find that the transmitting instrument represented at fig. 7 of the Bell patent of March, 1876, has in the cone A (which, as stated in the said patent, "is used to converge sound-vibrations upon the membrane") substantially such a speaking-tube. And in like manner I find that the cone L of the receiving instrument of the said Bell patent of 1876 is such a tube for listening. If, on the other hand, the term "speaking-tube" be employed in the ordinary acceptation in which it is generally used, that is, to denote a pipe of considerable length in proportion to its diameter, for the purpose of conveying sound, then I should be of opinion that a mere mouthpiece or earpiece such as are represented at fig. 7 of the Bell patent of 1876 would not amount in substance to such a speaking-tube.

Int. 38. Will you refer now to the description and drawing of the Reis telephone on pages 257 and 258 of Ferguson's "Electricity," and state whether you find there a speaking-tube, and whether with or without a chamber, for the purpose of conveying vocal sound to a diaphragm for the purpose of the electrical transmission of such sound, the tube or tube and chamber performing the same office, with reference to that diaphragm, as is done in the case of the Bell patent of 1877? And state, in connection with your answer, whether or not, and why, you agree with Mr. H. B. Renwick where he says, beginning at foot of page 46 of the record, "The box of Reis is so great in capacity, and extends so far downwards below

the diaphragm, that it will not act practically to concentrate the effect the air-undulations upon the face of the diaphragm," &c.

Ans. I find in the said Reis telephone, described in Ferguson's work, a speaking-tube, namely, the short straight, cylindrical tube between the mouthpiece M and the wooden box A. I also find that in said Reis telephone the said speaking-tube is used in connection with a chamber for the purpose mentioned in the question, such chamber being the interior of the box A, and the diaphragm being the piece of the bladder S, which closes the large hole at the top of the said chamber.

I do not agree with the opinion expressed by Mr. H. B. Renwick, as stated in the question, for the following reasons: The drawing shows that the speaking-tube, extending from the mouthpiece M to the box A forming the chamber, inclines downward or in a direction away from the said diaphragm; consequently, the tube directs the sound waves away from the diaphragm. If, under such circumstances, the sides and bottom of the chamber should be removed and a skeleton support for the diaphragm should be substituted in their place, the sound-waves would be permitted to escape laterally and downward, and a large portion of their force would not act upon the diaphragm. Whereas, when the sides and bottom of the box or chamber A are in place, as represented in the drawing of the Reis telephone, the sound-waves are confined, and must of necessity operate with greater force upon the stretched membrane or diaphragm than they would if the sides and bottom of the box were removed.

Int. 39. Mr. H. B. Renwick says, at tho top of page 26 of the printed record, with reference to the speaking-tube E, that the chamber in front of the diaphragm "is absolutely essential in order that the tubular part of the contrivance may convey the sound-waves to the diaphragm." What is your opinion as to the importance of the chamber, or as to the importance of the mouthpiece as to the matter of distinct and loud speaking or hearing; and what, if any experiments have you tried bearing upon this question, and with what results?

Ans. Some of the experiments before referred to by me in my

answer to question 35 were made with the mouthpiece and front of the box in their places, so that whatever chamber was formed by the front of the box existed in the instrument. Others of the experiments were made with the same instrument, with the mouthpiece removed, and so much of the front of the box as covered with the metallic plate also removed; so that no enclosed chamber existed in front of the metallic plate. I was not able to perceive any difference either in distinctness of articulation or the loudness of the tone, either transmitted or received, when the instrument was in two different conditions, from which I infer that neither the mouthpiece nor the chamber in front are essential. If a tubular mouthpiece with a speaking-tube be used in order to convey sounds from a distance to the metallic plate or diaphragm, then some device must, of course, be employed to hold the end of the speaking-tube to the diaphragm or plate; but in my opinion a chamber in front of the diaphragm is not essential for this purpose, and a narrow bridge straddling the diaphragm, or an arm for the purpose of holding the end of the tube, would, in my opinion, answer all practical purposes.

Int. 40. You spoke of the room where these experiments and the other experiments mentioned to-day were tried as a noisy room, Please tell us something more about it, tending to show whether it was or was not a room the conditions of which would furnish a severe test of the telephone apparatus used there.

Ans. The transmitting and receiving instruments were in two rooms of the shop of the Western Electric Manufacturing Company on New Church Street in this city, close to the lowest station of the Metropolitan Elevated Railroad Company, where trains are continually arriving and departing, and where, consequently, there is not only the rumble of the trains in motion, but the noise of escaping steam from the locomotives and of the compressed air from the air brakes is heard almost continuously, in addition to the noise of the carts on the street.

Int. 41. What do you think is the use of the chamber in front of the diaphragm in the Bell Patent of 1877, and also in the defendant's telephones?

Ans. The chamber itself, so far as my experiments inform me, or

my judgment, is of no practical value for the purpose of confining the sound. The plate which forms the chamber serves as a holder for the end of the tube, and for this purpose might be replaced by any kind of a skeleton device, such as an arm, bridge or spider, which would hold the tube in place. The said plate also acts as a cover to keep out dust, and when used for this purpose, it should not bear upon the diaphragm, so that a slight chamber or space between the cover when used and the front of the diaphragm is required to prevent the contact of the cover with the diaphragm.

Int. 42. Have you made any experimental use of any of the common receivers testified as used by Mr. Gray in 1874 or 1875, showing whether, either for the purpose of talking or listening, the diaphragm by itself, without either chamber or speaking-tube, is satisfactory and sufficient?

Ans. In conjunction with Mr. William M. Goodridge, I made a number of experiments with the following common receivers, testified as used by Mr. Gray at the date mentioned, namely, "Defendant's Exhibit Gray's Resonant Box Magnet Receiver," "Defendant's Exhibit Diaphragm Box Magnet Receiver," "Defendant's Exhibit Gray's Concave Metallic Diaphragm Magnet Receiver," each of the said exhibits being used to receive musical tones from vibrating reed transmitters, and to receive articulate speech in connection with an Edison carbon transmitter at the transmitting end of the line. In all of the said experiments the exhibits were used for the purpose of listening or as receivers, and in some of the experiments plain discs of sheet-metal were employed in connection with the magnet, such discs being similar to the solid head of the tin box of "Defendant's Exhibit Gray's Resonant Box Magnet Receiver," without either the cylindrical wall or the perforated cover of the box. The experiments showed me that the plain disc by itself, without either chamber or speaking-tube, is, when used in connection with an electro-magnet, satisfactory and sufficient to enable either musical tones of different pitches or speech to be made distinctly audible to the listener.